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JOURNAL OF CHEMICAL EDUCATION

for January, 1938

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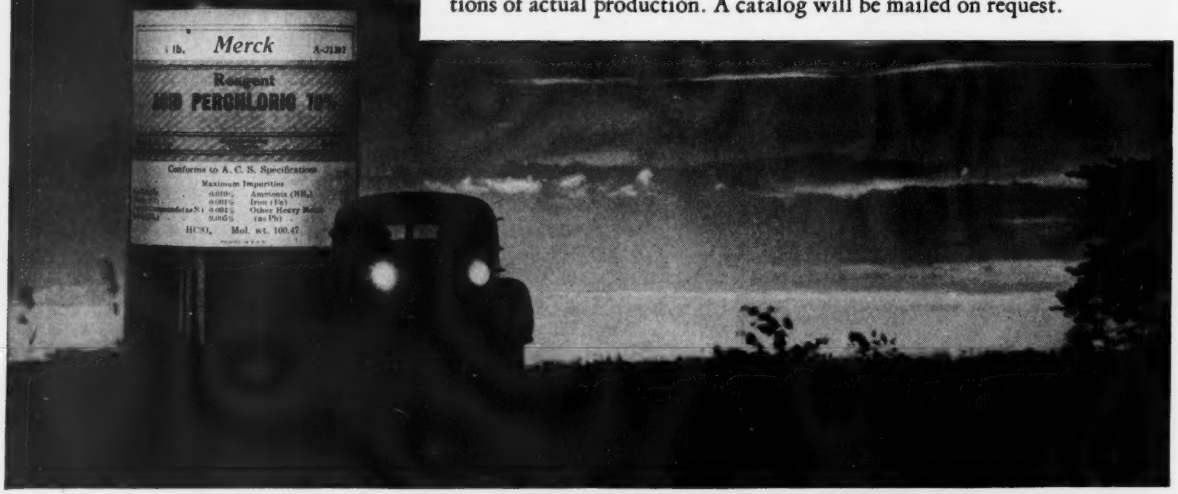

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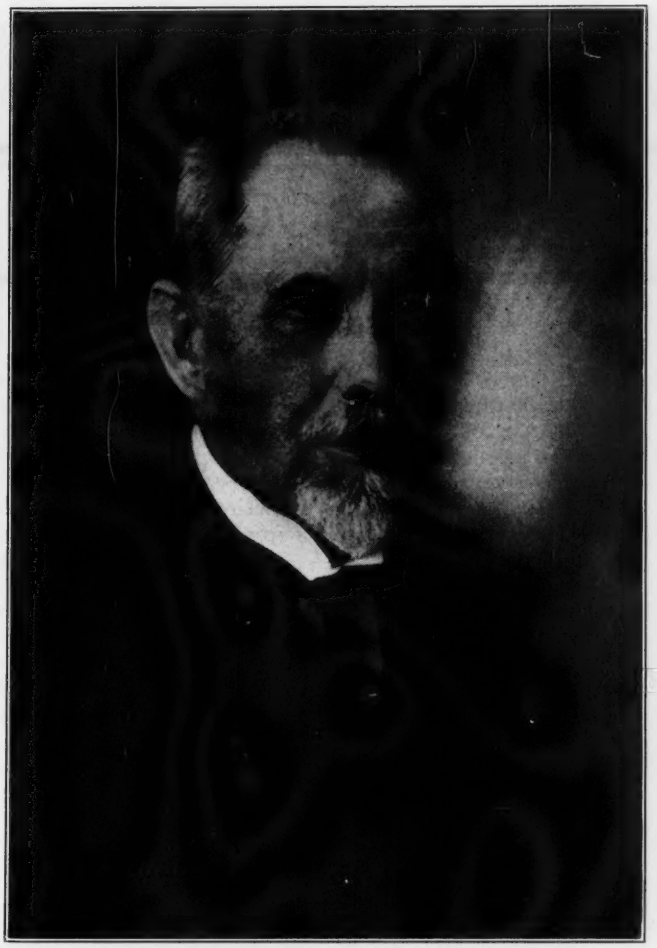


S. P. L. SØRENSEN (1868–)

ON ONE occasion, Professor Sørensen was addressed as the "father of pH." He smiled and said, "It was a nice idea, was it not?" The creator of this (1909) and other nice ideas was born on January 9, 1868, on the Danish island Zeeland. In 1886 he entered the University at Copenhagen where he had a brilliant career, being gold medalist in 1889 and 1895. He did not take his doctorate until 1899, because he was busy practicing his profession: assistant at the Geological Society (1890–91), consultant to the Naval Laboratory (1896–01), assistant at the Technical High School (1892–01). His demonstrated ability led, in 1901, to his appointment, as Kjeldahl's successor, to the Directorship of the Chemical Section of the Carlsberg Laboratory, a position that he has filled with distinction.

The printed record of his work is embodied in about one hundred papers, which have brought him an international reputation. The early publications, as might be expected of Jørgensen's student, deal mainly with critical studies of the preparation of inorganic salts. He later turned his attention to analytical questions, particularly primary standards, and to him we are indebted for the introduction of sodium oxalate.

The great bulk of his investigations have been biochemical, and he has interested himself especially with amino acids, enzymes, and proteins. His formol titration of amino acids is an indispensable aid. As an authority on fermentation, he is much consulted by manufacturers of alcohol, yeast, etc.

Recognition of his accomplishments have come in abundance. Honorary degrees, professorships, memberships in learned societies, medals, orders, decorations, have been conferred on him in Denmark, Finland, Sweden, Poland, Belgium, France, Spain, England, and America, but withal he has remained a kindly, modest gentleman, beloved by all who have had the privilege of knowing him.

(*Contributed by Ralph E. Oesper, University of Cincinnati*)

EDITOR'S OUTLOOK

FRANCIS P. GARVAN. Although this note of appreciation is necessarily belated, it would be singularly inappropriate for the JOURNAL OF CHEMICAL EDUCATION to regret in silence the passing of so stalwart and generous a friend of chemistry as was Francis P. Garvan.

The history of Mr. Garvan's awakened interest in chemistry, of his vision of a strong American chemical industry, of his administration, as president of the Chemical Foundation, of chemical patents acquired by wartime seizure, of his intense and practical interest in chemical education in the broad sense of the term, and of his strong support of applied research and of chemical literature in general has been often told, and is undoubtedly familiar to all our readers. For his innumerable services to the science and industry, in which he has been sympathetically and intelligently supported by Mrs. Garvan, he has received practically every American honor and award for which a layman is eligible.

One of the first of the worthy projects to attract Mr. Garvan's attention, and to win his support and that of the Foundation was the infant JOURNAL OF CHEMICAL EDUCATION. The Division of Chemical Education of the American Chemical Society, then scarcely freed of its swaddling clothes, was trying to cultivate a community of interest among teachers of chemistry, to afford opportunities for mutual exchange of ideas and experiences, and to serve as a cooperative society devoted to the continuation self-education of its members. It had felt keenly the need of a medium of publication to supplement, to record permanently, and to make generally available the proceedings of its meetings. Through the energy, enthusiasm, and optimism of Dr. Neil E. Gordon it had made a beginning, but it faced years of uphill struggle. The impetus given to the project by the support of Mr. Garvan and the Foundation, and by the services of its able business manager, Mr. Wm. W. Buffum, is visible in any complete library file of the publication.

Unhampered by the necessity of keeping one eye on the current financial statement during the formative period of its growth, the JOURNAL was able to expand rapidly, to attempt to seek out and fill hitherto unsuspected needs, and to indulge in some costly, yet worthwhile, experiments. During the period of Foundation prosperity the JOURNAL was able to reveal potentialities that otherwise must have long remained dormant, to seek out hundreds of potential friends, who in the natural course of events might have been attracted to it but slowly, and to make itself an indispensable item in the professional literature of many of its readers. It did, admittedly, set a level of publication volume and of production expense that could not subsequently be maintained on a self-supporting basis, but while doing so it had an opportunity to evaluate its own functions, to select for retention the most essential, and to build an unshakable foundation of advisory, contributor, and reader support, and of general public good will. Gratitude for that opportunity will long keep green the memory of Francis P. Garvan among all who have been vitally interested in the fortunes of the JOURNAL.

EARLY TEACHING *of* SCIENCE *at the* COLLEGE *of* WILLIAM *and* MARY *in* VIRGINIA

GALEN W. EWING

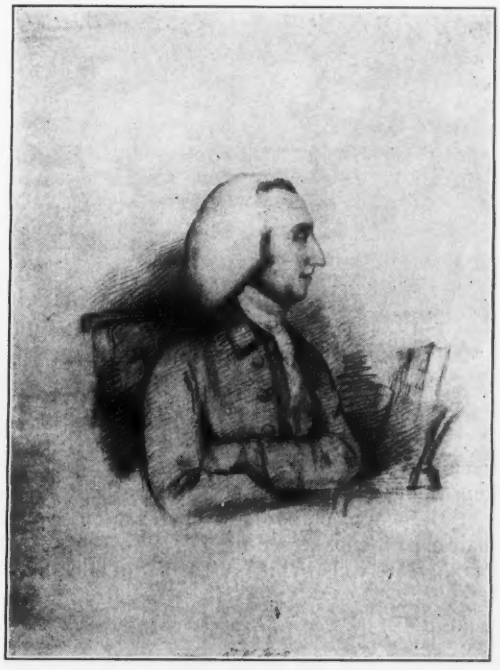
Chandler Court, Williamsburg, Virginia*

THE first permanent English settlement in America, at Jamestown, Virginia, in 1607, was composed of men who came to the New World, not primarily to make new homes, not to escape persecution, but to make their fortunes through the gold and silver and other natural wealth which they had heard were to be found abundantly in this marvelous land. But when they arrived, they found no such fabulous bounty, and were forced to give all their attention and labor to maintaining themselves against the perils of famine and disease and unfriendly Indians. In spite of their numerous troubles and disasters, the Colony grew and prospered, until, by the end of the century, the settlement covered the entire tidewater area of Virginia.

As the Colony gradually increased in stability, the settlers were joined by immigrants of good family, culture, and education, and there developed a stratified society very much like that of London. The sons of the "First Families" were sent to the mother country for the completion of studies which had begun at the home fireside or in the parish rectory. Considering the difficulties of ocean travel and the expense which was impracticable for all but the most wealthy, it is not surprising to find the colonists repeatedly discussing the founding in the Colony of an institution of higher learning.

It was, indeed, only ten years after the first landing that, in 1617, a college had been planned for Henrico, near the present Richmond; but this soon fell a sacrifice to the great Indian massacre of 1622. The movement finally became successful, when, in 1693, a charter was granted by the King and Queen for an institution to be known as "The College of William and Mary in Virginia." The purpose was stated in the charter: "Forasmuch as our well-beloved and faithful subjects, constituting the General Assembly of our Colony of Virginia, have had it in their minds . . . to make, found and establish a certain place of universal study, or perpetual College of Divinity, Philosophy, Languages, and other good Arts and Sciences. . ."

The plan of organization of the College was taken directly from the accepted practice in the English Universities, known as the "Oxford Curriculum." There were to be three schools: the Grammar School, which carried a student through the higher classics; the Philosophical School, where one professor was to teach Moral Philosophy, including rhetoric, logic, and ethics, and another Natural Philosophy and Mathematics, including physics, metaphysics, and mathematics; and, thirdly, the Divinity School which was entirely post-graduate. Four years' study in the Philosophical School entitled a student to the degree of Bachelor of Arts, and seven years to that of Master of Arts.



(*Courtesy Herbert L. Ganter*)

DR. WILLIAM SMALL
PROFESSOR OF NATURAL PHILOSOPHY AND MATHEMATICS, COLLEGE OF WILLIAM AND MARY, 1758–1764

* Present address: 342 Judson Court, 1005 East 60th Street, Chicago. Ill.

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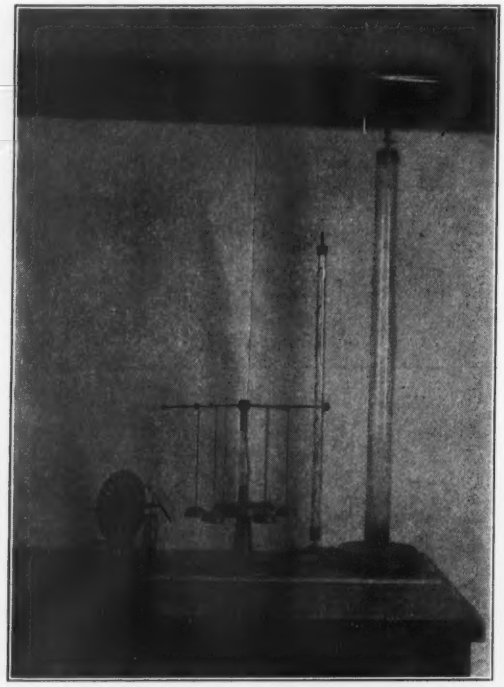
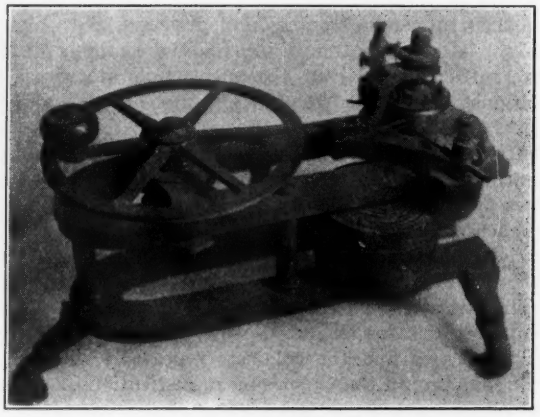
The College of William and Mary first opened its doors in 1697 with only the Grammar School in operation. The first Philosophical chair established was that of Natural Philosophy and Mathematics in 1712. The others followed in due course.[1] This first professorship was held by some nine men up to the Revolution, each serving from one to twelve years. Only one of these was outstanding in his profession, Dr. William Small, who served from 1758 to 1764. Of the others, half were clergymen of the Church of England most of them possessing a good general education, but not specially fitted to teach science. The Rev. John Camm, for instance, held for a few years the chairs of Moral Philosophy and Natural Philosophy and Mathematics as well as his proper field of Divinity.



OLD APPARATUS IN THE POSSESSION OF THE COLLEGE OF WILLIAM AND MARY. WIMSHURST MACHINE, ELECTROSTATIC BELLS, SPIRAL DISCHARGE TUBE, GUINEA AND FEATHER TUBE*

With the coming of Dr. Small, however, natural science came into its own. He was enthusiastic about his subject, and was a convincing teacher, as well as an ardent scientist. His influence was felt not only in the College, but in the court of Governor Fauquier, at whose table he was a frequent guest, and, indirectly, through the whole colony as well. Governor Fauquier was himself greatly interested in the sciences, and he and Small led discussions of all sorts among the youth of the city.

One of these young men on whom a great impression was made was Thomas Jefferson. There is no doubt that it was largely due to his stay at William and Mary under the tutelage of Dr. Small that Jefferson's ideas of the dignity of man rose and developed. Jefferson said of him that "he fixed the destinies of my life," and he undoubtedly meant by this that those free conceptions which animated his career were largely influenced by his associations with Dr. Small, who, as the professor of the natural sciences, was the enemy of all the narrow dogmatisms of the old philosophy.



AN OLD HAND GENERATOR IN THE POSSESSION OF THE COLLEGE OF WILLIAM AND MARY. PROBABLY ONE OF THE THREE PIECES OF APPARATUS SAVED FROM THE FIRE OF 1859

Dr. Small's most lasting contribution was the innovation of the modern lecture system in William and Mary, and, it is believed, in all America as well. This was a great departure from the system previously universally practiced, of pure memory lessons and recitations by questions and answers, which were either printed in textbooks or dictated by the professors. It is interesting to note that the introduction of the lecture and demonstration method into the chemistry course at Harvard did not occur until the year 1851,[2]

[1] As the name of the great Robert Boyle is connected with the early progress of the College, it should be pointed out that this had no relation to the scientific activity either of the "sceptical chymist" or of the College. The executors of Boyle's will were directed to dispose of the bulk of his estate for whatever charitable or pious object they might see fit. They purchased therewith the Manor of Brafferton in Yorkshire, England, the income from which was to be used to propagate the Gospel among the infidel. Part of this was alloted to the College of William and Mary for the support of an Indian school. The College, in the year 1723, constructed a building for this purpose, which was called "The Brafferton" and still stands. In it eight to ten Indians were maintained until the Revolution cut off the income. The Brafferton was used as residence by Professors P. K. Rogers and W. B. Rogers, hereinafter mentioned.

* The "Guineas" are coins stamped "R. Walker's Patent. No. 13½ B4" and a crown. The only clue known to the writer as to the maker's identity is the fact that a Ralph Walker was apprenticed in 1747 to the well-known maker of telescopes, George Sterrop of St. Paul's Churchyard, London. It seems probable that this is one of the three extant pieces of apparatus purchased by William Small, though not appearing in the fragmentary list.

[2] Life and Letters of William Barton Rogers (*cf.* Bibliography), Vol. I, p. 192.

some ninety years after its introduction at William and Mary.

Dr. Small returned to England in 1764, where he became associated with James Watt, inventor of the steam engine, and with Erasmus Darwin, an eminent scientist, the grandfather of the author of "The Origin of Species." He was under a commission from the College to purchase a considerable collection of scientific apparatus. The College Library has preserved a folded sheet of paper in Dr. Small's handwriting, enumerating a part of this purchase. This partial list is given herewith.

"Brought forwards	£ 178–10–0
The Fountain Experiment in Vacuo &c. in open air with a Bason &c.	3– 3–0
A Lung's Glass	10–6
The Barometer Exper[t]	15–0
Wire Cage for breaking Glasses with 6 brass caps with Valves	1–11–6
Plates for Attraction & Cohesion	0–15–0
A Pendulum to Swing in Vacuo	2– 2–0
A Set of Glasses for the Air Pump	3–13–6
6 Pound of Quicksilver	1– 4–0
A Dipping Needle Compass 9 Inches Diam. with Needles for the Dip	15–15–0
A Horizon[1] needle with a center Pin Works for it to stand on for the variation	0–18–0
	£ 208–17–6
"Brought over	£ 208–17–6
a monichord	4– 4–0
A machine for the Resistance of the Air according to M[r] Robinson	3–13–6
A Standard Barometer	2–12–6
The 5 Platonic Bodies	1– 5–0
A Cone dissected	0–12–0
To Packing all the above	2– 0–0
"Peter Dolland	
The Acromatic Telescope with a Triple Object Glass 3 1/2 feet focus, two Eye Tubes for Astronomy & one for Day Objects	15–15–0
A best double microscope &c	7– 7–0
A Solar Microscope with Apparatus	5–10–0
The Reflecting mirror a true parallel Glass	
A 12 Inch Concave Mirror, a flat Mirror	4– 0–0
A 6 Inch Concave Mirror	15–0
5 Lenses of different Sorts in Frames	3–10–0
2 best Prisms	3– 0–0
A Water Prism	2– 5–0
A Set of small Prisms in a Case	1–11–6
Two Specula on a Frame to shew a number of Reflexions	1– 5–0
3 Parall: Glasses 2 Inch: Diam. for taking the Sun's Altitude in Mercury	0– 6–0
A Square Par: Glass 6 Inch: Diam. in a Frame	1– 1–0
An Object Glass for shewing the Rings of colors to be us'd with the Plane Glass	1–11–6
A Square Mahogany Tube with an Object Glass & a Number of Eye Glasses to shew the Direction of the Rays of Light in Eye Glasses	2–12–6
Packing the above	0– 5–0
"Edwd Nairne*	
	£273–19–0
An Electrical Machine	10–15–0
A Glass Jarr	2– 8–0
5 Glass Syphons	7–6
A model in Glass to show the manner of Intermitting & Reciprocating Springs	2–14–0
17 Capillary Tubes	6–6
2 Glass Models of Pumps	4– 4–0
2 Glass Parallel Plains	18–0
A Glass Jarr, for the Hydrostatic Balance, the Screw, wheel & Axle Compound & other Levers & Weights, Wedges & Weights, Pullies & Weights & ye 6th Mechanic Power, all fix on 2 Brass Pillars	20– 7–0
A Brass Circular Carriage	3– 8–0
A Mahogany inclin'd Plane w[th] a Quadr[t] which sets to any angle w[th] Scale & Nest of weights 164 [os] Troy	4–16–0
Dr. Barker's Mill[3]	4– 4–0
An Instrument to try the Force of falling Bodies	3–17–0
	£ 332– 4–0"

Note especially that the total is over £300 up to this point, and the total of the complete list may have been larger. It is not known with any degree of accuracy what this would amount to in today's equivalent money values, but certainly as much as $3000, and perhaps considerably more. It is highly significant that the College was willing to invest such an amount in scientific equipment, and this formed what was, without doubt, the best collection of its sort in America.

An incident which goes to show the importance attached to science in these days was the conferring upon Benjamin Franklin of the degree, Master of Arts, in 1756, the only honorary degree given by the College prior to the Revolution. This degree was accompanied by a diploma which warmly testified to his merits "on account of marvellous Discoveries in Natural Philosophy conceived by him and published abroad throughout the entire republic of Letters . . . ."

The Revolutionary War was ruinous to the College. The buildings were occasionally used for quartering troops as Williamsburg was alternately held by British and American forces. It was only with difficulty that the library and scientific apparatus were preserved from harm. The exercises of the College were only nominal and the students few and far between. After the close of the war it was several years before the College could get back to normal. That it did so successfully was due to the devoted zeal and ability of its President, the Rev. James Madison, and Thomas Jefferson, who, as Governor of the Commonwealth and a Visitor of the College, had his residence in Williamsburg during the year 1779.

In this year, Jefferson presented a bill to the legislature, designed to change the organization of William and Mary into that of a university for the state. Although the bill was not enacted, considerable changes resulted from the close coöperation of Jefferson and President Madison. This reorganization was evidenced in particular in a new list of professorships and

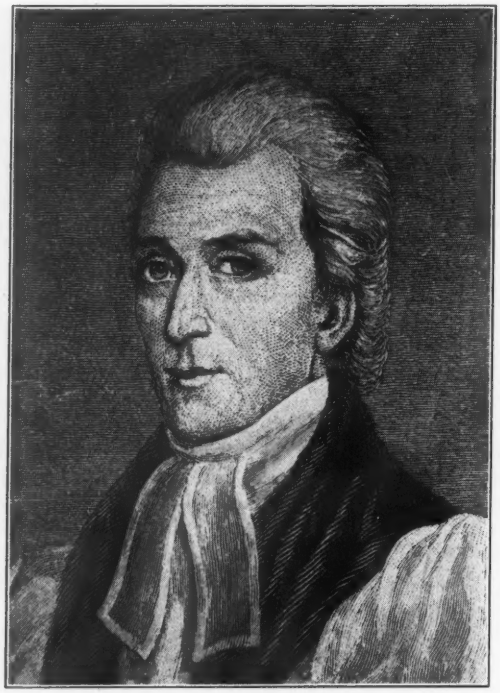
* Edward Nairne was born in 1726 and died in 1806. He was one of the most outstanding manufacturers of scientific instruments of his time. The Royal Microscopical Society has a microscope by Nairne to which is ascribed the date 1745.

[3] Barker's Mill is a device to produce rotary motion from water pressure by a series of reaction jets, similar to the familiar lawn sprinklers of today.

in the abandonment of the old Oxford curriculum in favor of the modern system of electives.

The Grammar and Divinity Schools were abolished. There were instituted a Professorship of Law and Police, one of Anatomy, Medicine and Chemistry, and one of Modern Languages. To the Professorship of Natural Philosophy and Mathematics was added Natural History, and to that of Moral Philosophy, the field of "Law of Nature and Nations" and Fine Arts.

The policy of allowing students to elect their studies was here introduced for the first time, long before it was adopted by any other American college. Presi-



(From C. L. Goodwin, "The Colonial Church in Virginia." Courtesy Morehouse Publishing Company)

JAMES MADISON, D.D.
PRESIDENT OF THE COLLEGE OF WILLIAM AND MARY, 1777 TO 1812; FIRST BISHOP OF VIRGINIA

dent Madison wrote in a letter to President Stiles of Yale College, dated August 27, 1780, ". . .The Doors of ye University are open to all, nor is even a knowledge in ye ant. Languages a previous Requisite for Entrance. The Students have ye Liberty of attending whom they please, and in what order they please, or all ye diffr. Lectures in a term if they think proper. The time of taking Degrees was formerly ye same as in Cambridge, but now depends upon ye candidate. He has a certain course pointed out for his first Degree, and also for ye rest. When Master of Either, ye Degree is conferred."

The courses leading toward the several degrees were (in 1792) the following. For the degree of Bachelor of Arts, the student must be acquainted with the first, sixth, eleventh, and twelfth books of Euclid, plane trigonometry, surveying, algebra, spherics, conic sections; he must have acquired a knowledge of Natural Philosophy as far as it relates to the general properties of matter, mechanics, electricity, pneumatics, hydrostatics, optics, and the first principles of astronomy; he must be acquainted with logic, the belles lettres, rhetoric, natural law, laws of nations, and the general principles of politics; he must also have a competent knowledge of geography and of ancient and modern languages.

For a master's degree, the student must have an intimate acquaintance with science in general, or he must have distinguished himself for his researches in a particular science.

For the doctor's degree, the candidate must prove himself deeply versed in the science in which his degree is to be taken. (It is to be noted that the word "science" as here used refers to the whole fields of academic learning, and not specifically to what we call sciences, which were considered branches of philosophy.)

In 1795 there were thirty or forty students in philosophy and law, with the philosophers increasing more rapidly than the lawyers. The College possessed over three thousand volumes of selected works in its Library, and its philosophical apparatus remained the best on the continent.[4]

Jefferson expressed his opinion of the College in the following complimentary terms. "What are the objects of an useful American Education? Classical knowledge, modern languages, chiefly French, Spanish and Italian; mathematics, natural philosophy, natural history, civil history, and ethics. In natural philosophy I mean to include chemistry and agriculture, and in natural history to include botany, as well as the other branches of those departments. It is true that the habit of speaking the modern languages cannot be so well acquired in America; but every other article can be as well acquired at William and Mary as at any place in Europe." This opinion is especially significant coming from Jefferson, himself a great educator, who was personally widely acquainted with academic circles of Europe and America.

The first science teacher after the Revolution was James Madison, who had come to the College in 1773. He became President in 1777, which position he held until his death in 1812. After the disestablishment of the English Church, he was made first Episcopal Bishop of Virginia. He was a member of the American Philosophical Society and contributed a number

[4] According to a letter apparently written by St. George Tucker to Rev. Jedediah Morse in 1795 and quoted by Dr. Lyon G. Tyler in the *William and Mary Quarterly Magazine*, 1st ser., **2**, p. 195.

of original papers to its and other scientific journals. Like his predecessor, William Small, his first asset was an ability to deliver forceful and vitally interesting lectures. He was a great favorite among his students, one of whom wrote in 1804 in these glowing terms.

"The character of Bishop Madison is an interesting one. In his life and habits he is perfectly systematic and regular; in his disposition, placid and indulgent; in his manners, the perfect gentleman; and in point of scientific knowledge he is undoubtedly a finished scholar. As a tutor, he certainly stands in the first rank. He strives with indefatigable zeal to open and expand the mind of the student, and his manner of illustrating is plain, intelligible and convincing. In his opinions of every kind, he is liberal and indulgent. The priest is buried in the philosopher, for he embraces no opinion that philosophy will not justify. With a perfect knowledge of mankind, he is at once able to discover virtue and merit wherever they exist—qualities which he treats with respect in every condition of life, while their opposite vices meet with his invariable neglect and disapprobation."

Another student, in 1799, writes, ". . . But from all the other studies put together, I do not promise myself half the pleasure I receive from N. Philosophy. The Lectures on Magnetism and Central Forces were particularly pleasing to me for altho the theories of Magnetism are extremely chimerical, and indeed some of them absurd and ridiculous in my estimation, yet the phenomena are so curious, beautiful, and interesting that they are truly entertaining. But the doctrine of Central Forces, is not so obscured with any of these fanciful theories, here the laws are beautifully explained, and the phenomena satisfactorily accounted for. The Whirling Table is certainly one of the most beautiful machines that was ever invented for the illustration of Philosophical phenomena. Upon the whole I think these lectures far preferable to any yet delivered."

The College Library has in its vault a notebook containing in its two hundred pages "A Compendium of Lectures as delivered by James Madison President of William and Mary," taken from his lectures by "Robert D. Murchie William and Mary Virginia 1809." It is probable that Murchie took rough notes during the lectures and recopied and reworded them afterward, for the whole work is remarkable for its neatness and order. Extensive quotations will not be out of place, as they give evidence as to the content of the Natural Philosophy course of the time and as to the Bishop's remarkable personality as well.

The index of lectures is as follows: (the original is tabulated and includes page numbers) "Introductory; Of matter or bodies in general; Chemical Affinity; Gravitation; Magnetism; Motion; Central forces or doctrine of circular motion; Of bodies falling perpendicularly; Of pendulums; Mechanical Powers; Compound Mechanics; Wheel carriages; Electricity; Of the two electricities; Of electricity communicated to electrics; Of the effects of electricity upon plants, vegetables, etc.; Galvanism; Pneumatics; Of the properties of air; Of air as necessary to combustion, etc.; Of heat; Introductory to airs; Of some of the gasses (*sic*) [oxygen, hydrogen, nitrogen]; Of Nitrous air [including also 'Of the Carbonic acid, Of the analysis of atmospheric air']; Of Evaporation; Of Winds; Of Hydrostatics; Of the densities and specific gravities of bodies; Of Hydraulics; On Optics, Light; Colours; Of the manner in which rays of light are refracted in passing through glasses of different forms; Of the senses in general; Of Microscopes and Telescopes."

WILLIAM BARTON ROGERS
PROFESSOR OF NATURAL PHILOSOPHY AND CHEMISTRY, COLLEGE OF WILLIAM AND MARY, 1828–36. FOUNDER OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The following selections are quoted from the notes themselves.

"What is the design of natural philosophy? To become acquainted with the properties of natural bodies, investigate their causes, and thence to infer useful deductions. . . ."

"What are the inducements to study natural philosophy? They are very great and very numerous, and drawn principally from five sources. 1st, Its extreme utility. 2nd, The gratification which the mind feels in pursuit of it. 3rd, The novelty and grandieur of the subject. 4th, It is the best field for exercising the hu-

man intellects. 5th, It is the source of the sublimest conceptions of the author of the Universe....

"That matter is infinitely divisible may be demonstrated mathematically; but when we come to apply this principle to actual experiment, we shall find

BRONZE TABLET IN ROGERS HALL, COLLEGE OF WILLIAM AND MARY

that the powers of man have not arrived at that degree of perfection to be capable of carrying on the division to such an extent.

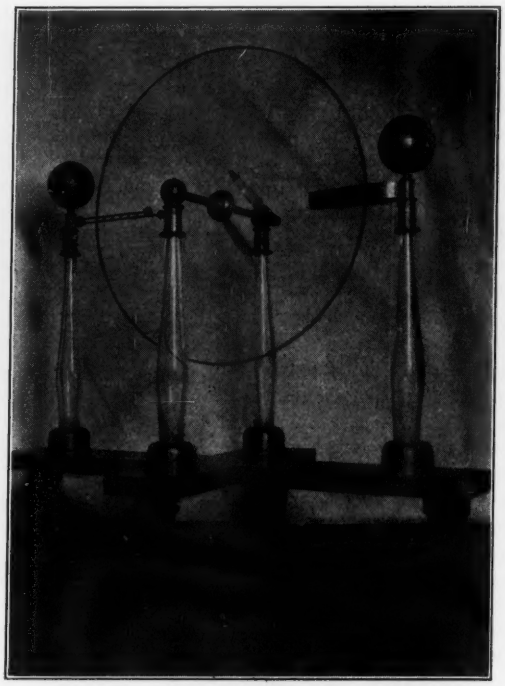
"General properties of matter are the following, Extension, Solidity,[5] Inactivity (or vis inertiae), Divisibility, and Mobility; to which have been added, Configurability, Porosity, Rarefactibility, Condensibility, Compressibility, and Elasticity....

"Some Chemists have supposed this force [chemical affinity], and the Newtonian attraction, on account of their analogy to be the same, and that the greater the gravity of any body, the greater also was its affinity. The cause of the latter is altogether unknown; however there is a remarkable difference observable in its laws and those of attraction. The latter acts between the largest masses, affinity takes place only between the smallest particles. Attraction operates at the greatest distances, affinity only in contact. Hence we see that if affinity be not entirely distinct from attraction, it can only be a modification of it.

"Do bodies really attract each other, or are they urged by an exterior force? Of this we are completely ignorant.

"The attraction of gravitation differs from that of cohesion or chemical attraction in this, that the latter may be destroyed, whereas the former is indestructible.

"The amusement which electricity affords us, is alone a sufficient inducement to study it. The cultivation of



AN OLD FRICTION MACHINE IN THE POSSESSION OF THE COLLEGE OF WILLIAM AND MARY. MADE BY E. S. RITCHIE, BOSTON. DIAMETER OF WHEEL, ABOUT THREE FEET

this science cannot fail to be particularly grateful to the inquisitive mind of man. Its peculiar advantage is, that it may be carried on as a recreation. I therefore advise every student to furnish himself with an electrical machine, and more especially, since the expense is small compared with the pleasure it will afford. He may then make discoveries of his own; and every one must be sensible that the satisfaction we feel from our own experiments is far superior to that which we derive from the discoveries of others.

"The manner in which the electric fluid is excited is a subject of curious speculation. As yet, it rests upon the uncertain foundation of conjecture.

[5] *Solidity* is here used not in the modern sense in contrast to *fluidity*, but rather to indicate the fact that no two bodies can occupy the same space at the same time. An experiment is described "to prove the solidity of bodies apparently the least solid," namely the trapping of air in a closed tube inverted over water.

"There seem to be three concentric strata of our incumbent atmosphere, in which, or between them, are produced four kinds of ---tions [word illegible], *viz.*, lightning, shooting stars, fire balls, and northern lights.

"It is necessary to make a few remarks on personal security during a thunder storm. . . . . If you wish a place of perfect security place yourself in a feather bed suspended to the ceiling by silken cords. But this is a method which will be resorted to only by the guilty wretch who trembles at the thought of death and not by virtue's ardent votary whose soul disdains the slavish fear of launching into the boundless ocean of eternity and supports him tranquil and unappalled amid the crush of worlds.

"The best definition of Galvanism seems to be, that it is the effect which small quantities of electricity produce, of convulsing the muscles and nerves of animals. Galvanism, it is true, embraces a variety of facts besides the above, but this definition should be adopted for the sake of distinctness.

"It is supposed, that there exists a very subtile and elastic fluid, dispersed throughout all the bodies of the universe, and capable of passing with more or less facility thro' them all. This fluid has been called elementary heat [caloric]; it is one of the principal agents the chemists employ in every process of decomposition, and in every enquiry by analysis.

"The atmosphere will dissolve a certain quantity of water. This is evident from its transparency. Take dry potash; weigh it in the dry state: you will find, in a short time, that it will have acquired weight: let it remain longer, and it will begin to run. Ice will lose part of its weight, when suspended in air, provided the temperature thereof is below the freezing point. Now in the first case, water was absorbed from the air: in the latter, it left the ice to combine with the air: in both the air was perfectly transparent: transparency is the test of solution: therefore the atmosphere will dissolve water. . . .

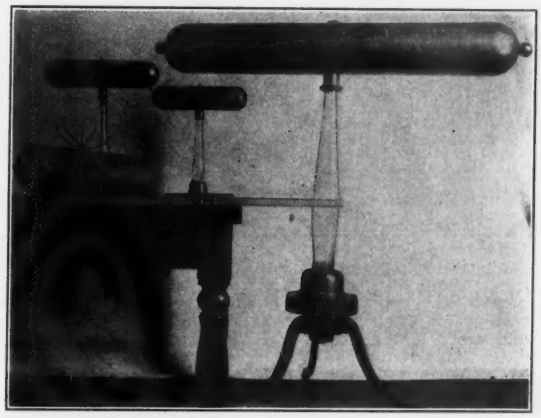
"How necessary a knowledge of the densities and specific gravities of bodies is, will best appear from attending to the following advantages which it affords. 1. It is necessary to determine the nature of fossils. 2. To determine what bodies are mineral and what are not. 3. To discover the purity of metals. 4. To discover genuine stones of value. 5. To determine the purity of liquors; which are mixed, and which are not.

"God said, let there be light, and there was light. But it is still a question what is light? Is it a mere quality of bodies, or is it itself a real body, a distinct species of matter? The more philosophers interrogate nature by judicious experiments, the more are they convinced that it is a real body. . . ."

He maintains throughout the old corpuscular theory of light in all its ingenious ramifications. The various colors are due to corpuscles of varying sizes: "Some colors are more agreeable to the eye than others, because they have less momentum, and of course do not irritate the retina of the eye so much." The caloric theory of heat is also dealt with at length.

There are numerous instances in these notes where it is quite apparent that demonstrations were performed by the lecturer. These include experiments in magnetism, the guinea and feather tube, electrostatic experiments using a friction machine, Torricellian vacuum, candle in a vacuum, reflection of heat, and the preparation of "nitrous air" from nitric acid and iron. He says, "There is a battery in the apparatus of William and Mary sufficiently strong to take away life."

The professorship of Anatomy, Medicine and Chemistry, established in Jefferson's reorganization, was held by a Dr. McClurg, but after he left in 1800, two professorships of humanity were instituted by the Visitors in place of chemistry, much to the regret of President Madison, who included lectures on chemistry in his natural philosophy course. A separate chair in chemistry was not established until 1908, while anatomy and medicine were never taught again as such. A class in botany was conducted as an extracurricular activity in 1806 by Dr. Girardin, Professor of Modern Languages, and later first President of the Maryland Academy of Science and Literature. A distinct chair of mathematics was established as early as 1784.



INSULATED CONDUCTORS IN THE POSSESSION OF THE COLLEGE OF WILLIAM AND MARY

The next important scientist at William and Mary was Dr. Robert Hare in 1818, though this was but a minor incident in the career of that distinguished chemist. He was at William and Mary only one year, leaving to take the chair of chemistry at the University of Pennsylvania, where he remained for forty years. He was not a brilliant lecturer, but was famous for his demonstrations, in which he used many pieces of apparatus of his own development. He invented the oxyhydrogen blowpipe, the hottest flame known at that time, before coming to William and Mary, and many other devices and processes subsequently.

He was succeeded by Patrick Kerr Rogers, M.D., who served from 1819 until his death in 1828. Rogers was an interesting lecturer, performing numerous

demonstrations partly with apparatus of his own construction.

Dr. Rogers published, in 1822, "An Introduction to the Mathematical Principles of Natural Philosophy." He was complimented highly upon this work by the aged Thomas Jefferson. In reply to Jefferson's letter, and referring to the newly established University of Virginia, Dr. Rogers says (March 14, 1824), "There is something in the organization of William and Mary which, independently of its location or other permanent disadvantages, must forever prevent it from being prosperous or successful; . . . I am inclined to think that when [the University] goes into operation we shall scarcely have occasion to open the doors of the old College. Even at present there is no reputation to be acquired here, and no encouragement to activity or zeal. . . ."

WILLIAM AND MARY COLLEGE, WILLIAMSBURG, VIRGINIA

Center, the main college building constructed from plans drawn by Sir Christopher Wren; left the Brafferton, home of Professors P. K. Rogers and W. B. Rogers; right, the President's House. All are still in use. This picture is an original lithograph made by John Millington's son, Thomas, in 1840.

But in spite of its troubles, the College did continue to open its doors every year down to the present time, excepting only a short period after the Civil War. The faculty continued to do its best even in the face of an uncoöperative Board of Visitors whose indifference was the cause of our professor's pessimism. Dr. Rogers, in the same letter to Jefferson quoted above, writes, ". . . Although we have a pretty large library in this place, we have very few books of real use to the profession, unless those on metaphysics, or what has been pompously denominated the philosophy of the mind, are to be considered as such. We have indeed the works of Bézout and Laplace, with several of the best treatises on chemistry, and the systems of natural and mechanical philosophy of Young and Robinson, which, after three years of solicitation, were reluctantly imported and received last summer. And of course we have access to most of the old writers on physics and mechanics, from Archimedes to Newton. . . ."

He favored Young and Robinson as the best English writers on mechanical philosophy. "Yet, I confess, I am not a convert to the theory of light and heat which is so ably defended by the former [Young]—the theory of undulations in a diffused universal medium. . . ."

The personal character of Dr. Rogers is presented in the following passages, quoted from Hon. A. H. H. Stuart, one of his former pupils and lifelong friend of his son and successor, William Barton Rogers.

"Dr. Patrick Rogers, at the time I became acquainted with him [1824], was about sixty or possibly sixty-five years of age, and a man of imposing presence. He was about six feet in height and was massively framed. . . . . His hair was white as snow, and his complexion ruddy and healthful. . . . . His manner was deliberate and dignified, but courteous and affable. In temperament, I judge, from the readiness with which his face would flush with each emotion, that he was sensitive and excitable. He was devotedly attached to and proud of his sons, and on more than one occasion I was struck with the interest which he showed in the amusements of Robert [his fourth son, aged 11, a flyer of kites]. . . . .

OLD MOTOR OF DYNAMO, ARMATURE LACKING. LABEL READS: "PRESENTED BY HON. JOHN TYLER, LATE PRESIDENT OF THE U. S. TO WILLIAM AND MARY COLLEGE"

"Dr. Rogers was a very learned man, and a most able, faithful instructor, and seemed desirous of keeping pace with the events of the day. As an illustration, I will refer to a single interesting incident. About the middle of the session, the newspapers of the State were teeming with accounts of the mysterious ringing of the bells in the elegant mansion of Colonel John Tayloe, of Mount Airy, in King George County. The bells would commence ringing violently all over the house without any visible human agency, or cause for so doing; and there was much speculation as to the true cause. In a few days thereafter, when the doors of Dr. Rogers' lecture room opened, the eyes of the students were greeted with the extraordinary spectacle of a whole system of bells in different parts of the room, ringing in concert, without any apparent cause for their activity. After we had looked for some time at the wonderful spectacle, they were suddenly and simultaneously silenced, and the professor then proceeded with a delightfully instructive lecture to show how the result had been accomplished, by currents of positive and negative electricity, thereby explaining all the phenomena connected with the Tayloe mansion on scientific principles. . . . .

"Dr. Rogers . . . enjoyed the reputation of being a profound scholar, and I can bear testimony that he was a careful and faithful teacher, singularly successful in his illustrative experiments before his class."

The pessimism of Dr. P. K. Rogers, regarding the usefulness of the College, was largely nullified by his own son, William Barton Rogers, one of America's most eminent scientists, who succeeded to his father's chair at the latter's death in 1828, and maintained the high standards of the educational opportunities at William and Mary. In his address introducing his first course in Natural Philosophy, the new professor said,

"To your sensibilities I will commit the task of appreciating the feelings I experience when, with the affections of a cherished son and pupil, I view the objects that surround me, associated as they all are with the recollections of a venerated parent and preceptor. Should I conduct you to the apartments in which for a series of years, with the calm dignity of true philosophy, he imparted to his pupils whatever is useful or sublime in physical science; should I display to your view the beautiful collection of philosophical instruments in which he took such pride, arranged with characteristic neatness and symmetry, and in some degree the products of his own ingenuity and zeal—you would feel these traces of his recent presence with a melancholy force, and friendship would sympathize with filial tenderness in the engrossing sorrow of the scene. . . .

"After these remarks, . . . I would solicit your attention to the views which I shall present in illustration of the *history*, *nature* and *utility* of Physical Science generally, and particularly that department of it usually denominated Natural Philosophy. In presenting these views, I propose—

"*First.* To allude to the relative proficiency of the ancient and modern worlds in Science and the Arts.

"*Secondly.* To exhibit some general ideas in relation to the material world; and,

"*Thirdly.* After defining the science of Natural Philosophy, and tracing the limits which separate it from Chemistry, to adduce a variety of illustrations to evince its utility. . . ."

Mr. Rogers met with immediate success. In his second year it is recorded that his classes were the largest in the College, and that the enrolment in the department of natural philosophy had not been equalled for the previous ten years. His class for that year is described by his brother Robert (age 16) writing to another brother, Henry.

". . .William has his hands full, having to lecture twice every day. His class are advancing very well indeed, and they are all very much pleased. William has divided his class into four divisions, which are called *clubs;* he meets one of them every night of the week except Saturday and Tuesday, and the students attend with the greatest alacrity possible. . . . I put my name down on the matriculation book, and made the 55th student. . . . William has made a number of fine models and is making many more, to explain conic sections, spherics and all solids. . . ."

Mr. William Rogers, also, was a matchless lecturer and demonstrator. He writes, ". . . I have just concluded my lectures on caloric, to my own satisfaction, and, I am well assured, in a manner agreeable to the class. No little difficulties arising from want of instruments, or from imperfection in those we possess, or any other trivial circumstances connected with my duties, give me the slightest uneasiness or perplexity. I employ every accessible means of illustrating my subject in an intelligible manner, and, when instruments fail me, I have recourse to explanations. The want of apparatus is certainly a serious difficulty in the way of a lecturer. But I believe that one course delivered under these circumstances is of more real value as an exercise to the professor than half a dozen assisted by the usual auxiliaries."

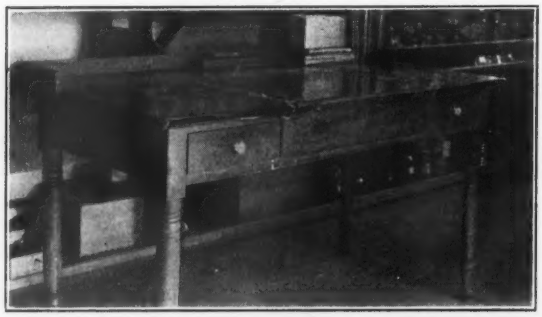
DR. JOHN MILLINGTON
PROFESSOR OF NATURAL PHILOSOPHY AND CHEMISTRY, COLLEGE OF WILLIAM AND MARY, 1836–1849

The College Catalog of 1829–30 gives as the content of the junior chemical course, "Inorganic and Organic Chemistry, the application of Chemistry to the Arts of Bleaching, Dyeing, Tanning, Metallurgy, Brewing, Distillation, the manufacture of Glass and Porcelain, etc., together with the Elements of Botany and Mineralogy." The senior natural philosophy course embraced "Dynamics, Mechanics, Hydrodynamics, Pneumatics, Acoustics, Optics, Magnetism, Electricity, Meteorology, Physical Geography, etc., together with the practical subjects of the strength of Materials, the construction of Watch and Clock work, of Roofs, Arches, Bridges,

Roads, the Steam Engine, and elementary principles of Architecture. . . . . The studies in all the Scientific Departments are conducted by means of Lectures and Recitations, from appropriate text books."

William Barton Rogers made a lasting reputation for himself at William and Mary, at the University of Virginia, where he spent some seventeen years, in the whole state of Virginia for which he made a complete geological survey, and in the nation at large, for his brilliant geological discoveries (partly in collaboration with his brother, Henry Rogers) and especially in 1862 as founder of the Massachusetts Institute of Technology. He died in 1882 while delivering a commencement address at the Institute, aged seventy-seven years.

In 1905, the Massachusetts Institute of Technology established a scholarship, known as the William Barton Rogers Scholarship, to be awarded annually to a student of William and Mary College selected by its faculty. In 1927, the College of William and Mary dedicated its new $300,000 hall of chemistry and physics to this great alumnus, calling it the William Barton Rogers Memorial Hall. In the main hallway is mounted a bronze tablet whose appropriate sentiment was composed by the late President of Harvard University, Charles W. Eliot, who was professor of chemistry in Rogers' first faculty at M. I. T. This placque is shown in the accompanying photograph.



DR. JOHN MILLINGTON'S DESK

Mr. Rogers was followed at William and Mary by Dr. John Millington who remained there thirteen years. He was already well known in London, having held appointments as Professor at the Royal Institution, being the friend of Faraday and Davy, Fellow of the Royal Society of Arts, Fellow of the Astronomical Society of London, Professor of Chemistry at Guy's Hospital, and Vice-President of the London Mechanics Institute. "At the age of fifty, as an engineer and teacher of science in his native London, he had approached greatness, though at a respectful distance."[6] In 1830 he had been in Mexico as superintendent of a group of British mines and of a mint. A few years later he had conducted a shop in Philadelphia, supplying "all the various machines, instruments, apparatus and materials, required for mechanical, philosophical, mathematical, optical and chemical purposes."[6] In 1835, he accepted the appointment at William and Mary.

He seems to have been successful as a teacher. In his first session at William and Mary thirty-seven students were enrolled in his class in chemistry and seven in the class in natural philosophy; but four years later, of the one hundred forty students matriculated in the College, seventy-four were taking chemistry and twenty-four natural philosophy.

He made for the College an extensive collection of geological and mineralogical specimens and materia medica. He also taught a course in surveying, a new subject at the College, for which he wrote a textbook, "Elements of Civil Engineering" (1839), of seven hundred sixteen pages.

In the chemistry stockroom of William and Mary at the present day is a small desk of ancient appearance, which bears in handwriting rendered scarcely legible by the years, the words "J. Millington 9–12–36[?]," inscribed on one of the drawers.

After the time of Millington, the science courses at William and Mary became more and more modern and contained little of historic interest. Student laboratory training had its beginnings in the year 1855, when, according to the catalog, "Students wishing to study Analytical Chemistry are allowed the use of the Laboratory and Apparatus." No mention is made of general laboratory work until 1889.

SIGNATURE OF JOHN MILLINGTON

In 1859 there was a disastrous fire which destroyed all but three pieces of the College's scientific apparatus. This was the end of much of the old equipment purchased a hundred years before by Dr. Small.

[6] JOHNSON, T. C., JR., in the "Dictionary of American Biography."

Thus William and Mary has had a history unique among educational institutions, being the first in America to introduce several highly important educational methods, notably the lecture method and the system of election of studies. Its undergraduate departments of science have been among the foremost in their fields from the earliest times even to the present day. Its great teachers of science of the past—Small, Madison, Hare, the two Rogers, and Millington—were generally recognized as among the outstanding men of their respective periods.

If the College has in recent years lost its unique position, it is not because its interest in the teaching of science has declined, but rather it is due to the fact that its ideals have become generally recognized and put into practice in many institutions. But its members never forget that it was a pioneer, and they take great pride in that memory.

PROFESSORS OF SCIENCE AND OF MATHEMATICS AT THE COLLEGE OF WILLIAM AND MARY IN VIRGINIA PRIOR TO THE CIVIL WAR

(Dates shown are the years when professors were appointed; dates of resignation or death are given only when a hiatus occurs in the series.)

Professors of Natural Philosophy and Mathematics

— Le Fevre	1712–1713
Rev. Hugh Jones	1717
Alexander Irvine	1729
Joshua Fry	1732
John Graeme	1737
Rev. Richard Graham	1749
William Small	1758–1764
Rev. John Camm	1766
Rev. Thomas Gwatkin	1770–1775
Rev. James Madison	1773

Professor of Anatomy, Medicine, and Chemistry

James McClurg	1779–

Professors of Natural Philosophy

Rt. Rev. James Madison	1784
Dr. John McLean	1812
Dr. Thomas L. Jones	1814
Dr. Robert Hare	1818

Professors of Natural Philosophy and Chemistry

Patrick Kerr Rogers, M.D.	1819
William Barton Rogers	1828
Dr. John Millington	1836
William F. Hopkins	1849
Benjamin S. Ewell	1848

Professors of Mathematics

Rev. Robert Andrews	1784
George Blackburn	1805
Ferdinand S. Campbell	1811
Robert Saunders	1833
Benjamin S. Ewell	1848

BIBLIOGRAPHY

Every student of the history of the College of William and Mary must be greatly indebted to that indefatigable historian, the late President Lyon G. Tyler, who has recorded all sorts of source material, largely in the following publications:

William and Mary College Quarterly Historical Magazine, First Series, 1892 to 1919.
Tyler's Magazine, 1919 to 1936.
"History of the College of William and Mary from its Foundation, 1660 to 1874."

Thanks are also due in very large measure to Dr. Earl G. Swem, Librarian of the College, who has indexed the above and other source material in his "Virginia Historical Index," **1935.** Other material used in this paper include:

William and Mary College Quarterly Historical Magazine, Second Series 1921 to date.
"Life and Letters of William Barton Rogers," edited by his Wife, Houghton Mifflin Co., Boston, **1896** (2 vols.)
"Dictionary of American Biography," Charles Scribner's Sons, New York City.
BRUCE, PHILIP ALEXANDER, "History of the University of Virginia, 1819–1919; the lengthened shadow of one man," The Macmillan Company, New York City, **1920.**
RITCHIE, JOHN, JR., "The American Association for the Advancement of Science," *New England Magazine*, new series, **18,** 639 (1898). (Portrait of William Barton Rogers.)
GOODWIN, EDWARD L., "The colonial church in Virginia," Morehouse Publishing Co., Milwaukee, p. 127. (Portrait of Bishop James Madison.)

I would entreat these wise and prudent fathers to consider diligently the difference between opinionative and demonstrative doctrines, to the end that they may assure themselves that it is not in the power of professors of demonstrative sciences to change their opinions at pleasure.—GALILEO

The CHIEF SIN *in* FIRST-YEAR COLLEGE CHEMISTRY TEACHING*

P. M. GLASOE

St. Olaf College, Northfield, Minnesota

IN ONE of our large midwestern universities this little episode took place. First-year chemistry students in this institution are numbered by figures of four digits, over fifty per cent of whom come with a credit in high-school chemistry. All are put into the same course; they are given the same lectures, the same laboratory work, and the same quizzes. Quite a number of the demonstrations shown on the university lecture table were given in the high school; a large number of the experiments were done in the high-school laboratory.

At the end of the course an instructor who had taken the trouble to look up the matter, had found that the grades of those with high-school credit were but a trifle higher than those without. His first sage conclusion was the same as has been given by hundreds of college and university teachers before him, "Those without high-school credit have caught up." Then, as he thought a moment, he added the alternative, "Maybe we have kept the others back."

In his doctor's dissertation on the subject, "Laboratory Instruction in the Field of Inorganic Chemistry," carried out in the College of Education, University of Minnesota, Victor H. Noll gives four out of one hundred sixty-four pages to the subject, "The Value of High-School Chemistry." The first conclusion based on his measurements is, "After two quarters of instruction we find no certainly reliable differences between the two classes." After a further technical statement based on his results, he says, "In view of these facts, it might well be argued that the university is not giving students who had chemistry in high school the full benefit of their training in the subject"; and again, "It may be that these students should be classified into groups on the basis of ability and previous training and that instruction should be differentiated according to this classification."

Dr. Noll is reluctant to admit that the passages just quoted have in them a serious indictment of our way of teaching first-year chemistry and so adds, as his final conclusion, "It seems, therefore, that if a student has the necessary intelligence and aptitude his chances for success in these courses are almost as good without previous training in chemistry, as they are if he has had a course in chemistry in high school—this not to be construed as an argument against the high-school course."

* Presented before the Division of Chemical Education at the Fourteenth Midwest Regional Meeting of the A. C. S., Omaha, Nebraska, April 30, 1937.

DR. NOLL'S SECOND PROPOSITION

I want to take up and discuss Dr. Noll's second proposition, "The university is not giving students who had chemistry in high school the full benefit of their training in the subject." The statement applies to every institution of collegiate grade that indiscriminately mixes first-year students with and without high-school chemistry.

Everyone knows that there is a wide variety of opinion as to the kind of high-school course that ought to be given in chemistry. It is well known that only a small percentage of the high-school graduates who have taken up chemistry go on to college or university. The question is therefore pertinent: Is the high-school course of such a nature as to be of real value to those who drop out of school as well as to furnish a satisfactory entrance credit to college? Does the present course as given serve both aims? Judging by the standard high-school texts now sold by leading book companies there is no really serious attempt made to vary the course to suit the two classes of students. We must conclude, then, that the requirements of the small number of high-school graduates that goes on to college really determines the kind of high-school course that shall be given.

There is at least a grave doubt that the course fitting a student for college also serves as the most satisfactory preparation for him who leaves high school to go out into life. In other words, it may well be that the standard set by the university imposes a certain kind of course on the high school which does not serve the best interests of the large number that stop with high-school graduation.

But, now, when students enter college and wish to prepare for medicine, pharmacy, or engineering they are compelled to take "first-year" college chemistry in order to meet requirements. The high-school course in chemistry is not accepted as a sufficient foundation for professional study.

Here is where the trouble begins. A great many higher institutions ignore high-school preparation in chemistry completely. All who register for first-year chemistry are put into the same class, given the same lectures, the same experiments, the same quizzes and examinations. In every institution the excuse is the same. High-school chemistry is as good as useless; students with credit from high school show little or no advantage over the others. In fact, says Dr. Noll, it would appear that students of equal mentality show

about the same accomplishment in college chemistry whether they have had the high-school course or not. In other words the high-school course is useless as a preparation for college chemistry. It is, then, worse than useless, for the student has spent a mininum of one hundred eighty hours in class, not to mention the time at home or out of class preparing the lessons for those hours, and at the end of the course the college professor pronounces judgment that the student would have been equally well off without it.

In one university the professor said that for ten years his department had kept a close record of all grades obtained at the end of first-year chemistry and had found little or no advantage going to those who came with high-school credit.

Isn't it pathetic? The high school stands accused of doing such a poor job of it that the student would be far ahead as far as mere measure of time is concerned, if he left out chemistry from his high-school course. But what reason have we to believe that the American high school is doing any better in mathematics, biology, physics, etc.? In fact, I have heard teachers in several of these branches question the value also of those high-school courses as preparation for university work. If the argument is sound it ought to be good policy to close up our high schools, let our youth get four years of aging experience anyway they can and then come to the university without predilections and wrong conceptions of the subjects they wish to pursue.

THE TROUBLE IS WITH THE UNIVERSITY OR COLLEGE

I believe that from the standpoint of pedagogy and psychology it can be shown that the trouble is with the first-year college chemistry more than with the high school. The *freshman procedure of mixing all first-year students, helter-skelter, whether with or without high-school credit is wrong:*

1. Because it is an injustice to the high school and the high-school student.
2. Because it is bad pedagogy. It does violence to all common-sense pedagogical principles.
3. Because it is bad psychology. You cannot foster interest by inane repetition of lectures and laboratory experiments. The university course should be more than a high-school course grown up.
4. What is really being done is that the high-school prepared students are being kept back until the others catch up. While the others are catching up, the former are chafing and being bored. They become laggards and drones. They lose interest, to the great injury of themselves, first, of course, then of the good name of the science. There are many youths who have gone into college or university chemistry with high hopes because of the interest gained in high-school chemistry, only to come out disgusted and dissatisfied, not only with the course but with chemistry in general.

WHAT GOOD PEDAGOGY REQUIRES

I have always understood that good pedagogy requires that the students should be kept "on their toes" with interest all the time. Fancy yourself in their position. You come to college with good standings in chemistry and look forward to continuing the study. Here you are placed side by side with the beginners; while the professor discusses chemical and physical change with elaborate demonstrations involving loud explosions, flares, and such educational experiments as hammering a wire flat on an anvil and passing it to the front row to let the first student burn his fingers on it, etc.; and while this must of necessity continue for weeks, the bright student with high-school credit sits there becoming more and more fixed in his opinion that he "has had it before." Then to add insult to injury he is directed to repeat a large number of experiments done before in high school. Of course, there is no denying that he has forgotten some of them, but the fact that he has had them before is beginning to act as a serious damper on his spirits, and long before the *professor has caught up* with his lectures or the elementary student has caught up with his necessary experiments, the prepared student has become weary of the whole affair and is now simply an auditor in the lecture room and a hanger-on in the laboratory. Now, that is what has been called having the elementary students "catch up"; there is no better illustration in academic life of successfully "holding back" the prepared students until the unprepared have caught up.

THE REMEDY IS SIMPLE

Correct pedagogy requires the complete separation of the two classes. Let us call the high-school credit class the "*A's*" and the others the "*B's*". The "*A's*" must be treated as if they knew something about chemistry. In this way you build up their self-confidence, instead of snuffing it out. You deal with each subject you take up as if you are building on their preparation. Instead of being able to rest upon the conclusion that they have had it before they will come face to face daily with the fact that they have forgotten what they learned in high school and will be compelled to look up their high-school text to refresh their memories. In this way, from the very first day, they will be compelled to be "on their toes"; there are things to reach for. They have to stretch instead of sagging back into a position of lassitude and inanition.

Good pedagogy has much in common with the training of race horses. You don't let your future racer loaf on the course; you tighten rein on him, give him the whip, and make him "lay into the harness." This must be repeated day after day for months until it becomes an unconscious ambition of the horse to beat his own record. It seems that it is only in academic circles, when high-school preparation is at stake, that we choose to do just the opposite. In horse training we don't even let a mediocre horse "set the pace" for the future winner; we bring out the best racer of the stable and make the horse we are training strain every nerve and muscle to beat him. When Dan Patch was being

trained, men on horseback rode along side in a dead gallop to give Dan something to run for.

The "*A's*" must be given an entirely different text book from the "*B's*." They mustn't even be able to compare notes and say their books are *almost* the same. Let the "*A's*" come to the conclusion that you are trying to pawn off on them a book which is different from that of the "*B's*" only in the fact that the "*A's*" book has a few more pages than the "*B's*," and they will lose a degree of their respect for the subject. You cannot afford the risk.

THE DEADLY PARALLELISM OF TEXTBOOKS

I have before me two textbooks by the same author. The one, of five hundred fifty pages, says the author, "is designed specifically for students entering college without high-school chemistry." This is the "*B*" book. The other, of six hundred fifty pages, "is adapted to the needs of students well trained in preparatory-school chemistry." This should be the "*A*" book. But what do we find? Looking at the Tables of Contents we find both books practically identical—and still worse, they are chapter by chapter the very same as the "Contents" of any standard high-school text. To use the two books at the same institution for the "*A*" and "*B*" courses would be a fatal mistake.

Last fall I chose books by two different authors for my "*A*" and "*B*" classes. I have persisted in treating the "*A*" students as advanced, and have attempted to make their course as unlike the high-school course as possible. This, I find, can be done by the introduction of the Periodic System during the second or third week, and by building on that they are never able to deceive themselves enough to say that they have had it before. We scrupulously avoid repeating a single high-school experiment in the laboratory. I am continually calling attention to what I expect of them as high-school graduates who have taken a course in preparatory chemistry.

THE LOGICAL RESULT

When you treat them in this way you soon become conscious that, while there are students in "*A*" who ought to be in "*B*," the average difference between the "*A's*" and "*B's*" is great: There is a decided carry-over from high school upon which to build the advanced course. In this way you are setting a standard higher than mediocrity. The gifted student finds plenty of subject matter that calls for his very best efforts; the weaker makes the effort of his life, not only to keep up, but to reach just as far as his ability will allow him.

That is my idea of doing justice to the student, to his high-school teacher, to the college or university, and to the subject of chemistry.

A STUDENT MICRO-PROJECTOR

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A MICRO-PROJECTOR is now an accepted tool in the laboratory. As a student project it proves to be most interesting and instructive. The materials are easily obtainable in the average science department, and the set-up requires only about ten minutes.

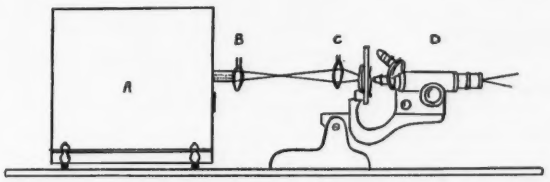
The best projectors on the market today are generally used in conjunction with a standard compound microscope, equipped with a sub-stage condenser, a 2× to 6× ocular and a 16, 8, or 4 mm. objective. A combination of the 4 mm. objective with a 3× to 6× ocular gives the best images for the ordinary specimens. For low-power subjects a 16 mm. with a 3× to 6× ocular is used. The image produced on the screen is eighteen to thirty-six inches.

The purpose of this article is to show how easily and quickly a micro-projector may be assembled by the students for lecture work or science programs. The discussion covers the arrangement of equipment, operation, and preparation of slides for demonstration.

ARRANGEMENT OF EQUIPMENT

The apparatus necessary for the construction of the micro-projector consists of a standard microscope, two bi-convex lenses, and a powerful source of light. In the drawing, (see Figure), is given an idea of the general set-up.

The beam of light, *A*, may be from a carbon arc lamp, a slide projector, or a 16-mm. moving-picture projector. The latter furnished with a 750-watt lamp is by far the best to produce an intense beam of light; however, the other two will serve the purpose. Unless the arc lamp is fitted with an automatic feed, the beam has to be adjusted quite frequently. Lens *B* should have a



GENERAL SET-UP OF MICRO-PROJECTOR
A, MOVING-PICTURE PROJECTOR—(LIGHT SOURCE). *B*, *C*, CONVEX LENSES AND HOLDERS. *D*, MICROSCOPE

diameter of forty-four mm. with a focus of ninety-five mm., and lens *C* fifty mm. in diameter with a focus of one hundred thirty-four mm. The grip arm of the microscope should be tilted so that the body-tube is in a horizontal position. This arrangement must be in perfect alignment.

DETAILS OF OPERATION

The source of light and the microscope are lined up about one foot apart. The bright spot is focused on the aperture of the sub-stage. The condensing lens, *B*, is then placed as close to the source of light as possible and lens *C* moved back and forth until the spot of light striking the focusing objective of the microscope reaches a maximum intensity. The lenses are then clamped to a ring stand. By far the most important part of this operation is getting the proper combination of objective and ocular. The best image produced on the screen is made by using a 16-mm. objective and a 5× ocular. This produces a bright field on the screen that measures at least thirty-six inches in diameter at a distance of ten feet. The tube holding the eye-piece may be removed if a smaller field is desired. The magnification is not as great, but the image is clear and sharp. Table 1 shows possible combinations and results.

TABLE 1

COMBINATIONS OF OCULAR AND OBJECTIVE

	Ocular	*Objective*	*Image*
1	10 ×	16 mm.	clear, sharp, large field
2	6 ×	16 mm.	good
3	6 ×	4 mm.	not as clear
4	5 ×	16 mm.	best
5	5 ×	4 mm.	fair

After an intense field of light has been obtained on the screen, it is time to insert the slides in the spring clips. The microscope should be steadied by means of clamps or supports to avoid any unnecessary shifting of the beam of light. A mechanical stage for the slides enables the whole field to be explored quickly and systematically. The images can easily be brought into view by adjusting the focus of the objective.

PREPARATION OF SLIDES

This projector proves invaluable to the chemistry students for the examination of crystals. It is better that the crystals be deposited on the slide from solution; otherwise, free particles will fall off as the stage of the microscope is in a vertical position. A small cover-glass sealed over the deposit will keep the samples indefinitely. The slides can be labeled and kept on file for future demonstration.

Another advantage given by the micro-projector is that of viewing the specimens under polarized light. An ordinary microscope can now be equipped with polarizing attachments.* These are inexpensive and allow for the study and examination of fibers, textiles, cross-sections of plants and tissues, and optical compounds, such as tartaric acid and the sugars. A detailed account of the method of making these slides may be obtained from *The Science Leaflet*.[1] Rotating one of the polarizers or inserting a sheet of mica changes the colorless crystals into a profusion of beautiful tints.

LIVING SPECIMENS

By using a cell slide, a drop of the biologist's culture of paramecia, amoebæ, or vorticellæ may be held in position by a cover slide. Imagine the enthusiasm awakened when the students see these microscopic organisms moving across the screen. In order not to kill the tiny one-celled animals by the intense heat of the beam of light, a cooling cell should be inserted between the lenses. If a projection cell is not available, a small Florence flask may be used. These living organisms may be kept alive for some time by placing a little water under the cover slide each day. To see these tiny creatures to the best advantage, one may have to worry a while with the lenses and focus of the microscope, but the time spent is quite worth while.

SUMMARY

A micro-projector as a student project may be assembled with ease. The materials necessary for this set-up are (1) a strong source of light, (2) two biconvex lenses, and (3) any standard microscope. All four parts must be as close together as possible to eliminate light leakage. A large square of cardboard or lead foil serves as a good screen. The intense beam of light passing through the two condensing lenses should be a spot of maximum brightness on the focusing objective of the microscope. The images may be thrown on a white wall or daylight projection screen. Best results are obtained in a darkened room. Slides made by the students of the science classes afford entertainment and instruction for programs.

* The Polaroid Corporation, Boston, Mass.

[1] PARSONS, G. H., "Slides for the polarizing microscope," *Sci. Leaflet*, **10**, 36–9 (Feb. 4, 1937).

QUALIFICATIONS *for* TEACHERS *of* CHEMISTRY*

A CHEMIST'S POINT OF VIEW

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I HOPE to approach this subject with the perspective of one not immediately involved in the detailed problems of secondary-school teaching, but who, nevertheless, has a considerable interest in it, as the human material with which I must work is the product of this teaching. I also intend to restrict my remarks to the question of the selection and the preparation of teachers in the secondary-school and junior-college levels. Whereas most of the things that I will say will, I know, be concurred in by my fellow scientists, I cannot refrain from taking this opportunity for expressing some of my own philosophy on the subject. As an outsider, I will be bolder and more dogmatic than would be becoming to the specialist. By such a procedure I will lay myself open to a more frontal attack by those whose opinions may be at variance to the ones that I express; but as it is our purpose to stimulate discussion of this subject and bring out in clear relief the different points of view, I may better achieve these ends by such means.

The matter of the adequacy of the preparation of secondary-school teachers should be and is a matter of considerable concern, not only to the specialist in education but also to the scientist and to the public at large. There is current a considerable belief that the quality of high-school teaching is declining rather than improving. The published report of the Committee of the American Chemical Society on High-School Teaching† states,

"There appears to be an almost general unanimity of opinion among university professors of chemistry, physics, biology, and mathematics that the high-school students who are now entering our universities, and those who have entered within the last ten years, are much inferior in preparation in mathematics and other fundamental and basic courses to similar students of a generation ago, and that the situation is tending, if possible, toward a worse condition. With this general opinion your committee is in agreement."

With this the trend for those students that enter college the situation must be at least as bad for those who do not, and this implies that the quality of our general education is diminishing. That such basic subjects as English, mathematics, and the sciences are not of the utmost importance for general education is a point of view that I contend to be untenable. There are those who would substitute for them subjects less rigorous and less valuable for mental training, but it should be pointed out that whereas the students in college will get some contact with these fundamental subjects those that do not go to college have a still greater need for them.

Let us analyze the problem of teacher preparation and the related problems of general education without regard to traditional methods. Let us do this in a manner frequently used by scientists, when they set up a limiting law to which reality can only be made to approach. In other words, let us investigate the elements of the problem, then set up an ideal solution, and finally discuss by what means we can best approach this ideal.

"Why teach" is the first question which concerns us. We spend a great deal of our available human effort upon education and a considerable fraction of everyone's life is consumed in being taught. We are endowed at birth with an anatomical structure which can be put to use when trained. We are not born with the skill necessary to make use of our mental and physical capacities. A child must learn to walk and talk, and even birds must learn to fly and seals to swim. The more complex our civilization, the greater the amount of effort that must be spent on training and developing our native capacities to adequately take part in it.

It seems clear, therefore, that the basic purpose of teaching is for the training and development of native faculties, both physical and mental. Our educational system does not fulfil its purpose and wastes both the effort and the student when it deviates from this fundamental purpose.

Besides being the seat of the feelings and emotions, the mind serves several functions among which are the retention of impressions (memory) and the processes of reasoning. It probably can justly be said that what training there is in our secondary schools is chiefly memory training. Although it is true that knowledge is a valuable asset, we must insist that the basic function of education is the training of faculties and not the im-

* Contribution to a symposium conducted jointly by Section C (Chemistry) and Section Q (Education) of the American Association for the Advancement of Science with the Division of Chemical Education of the American Chemical Society, at Atlantic City, New Jersey, December 29, 1936.

† *Ind. and Eng. Chem. News Edition*, **14**, 147 (1936).

parting of facts or knowledge. The old idea of a scholar as a man steeped in knowledge is not in keeping with modern thought. A thinking man rather than a knowing one would more nearly fit our present ideals. Our education should be toward a training in the use of knowledge, as well as in acquiring it.

We have little knowledge or skill in the training and development of the emotional faculties of our minds. It seems that this is a very important and neglected angle of education. It may be that many of our most important personal and social difficulties are caused by our untutored emotions. This is an enticing topic, but one that would take us far afield from our subject.

Practically every child of perhaps six to ten years old demonstrates a native capacity to think originally about matters which are almost unknown to him. Who has not been startled and surprised by original thoughts from young children? It is a serious accusation against our educational system that this faculty is in a great measure lost before reaching college age. It may have become dormant because of the lack of emphasis on its training and cultivation in both primary and secondary school. There are two reasons for this. The first is that it is easier for the teacher to give the pupils material to be memorized and then require the same to be parroted back in recitation or examination than to exert the strenuous efforts necessary for training the intellect. Under existing conditions the teacher is not compensated in proportion to the development of the pupils nor is the teacher's reputation based on it. The second is that for a teacher to develop thinking abilities in his pupils, his own capacities must be highly developed. As he is a product of the same educational system, we are blocked by a vicious cycle.

Another difficulty is a theory that mental training obtained in one subject is not useful in another. This has resulted in crowding the curriculum with bits of this and that type of descriptive material, which may or may not be useful later in life. It neglects, of course, the fact that descriptive details are soon lost to the memory, whereas developed skills are, in a large measure, retained. They are continually used on different bodies of facts. If the mental training acquired using one body of facts were not of use on another, it seems reasonable to contend that our educational system serves no purpose compatible with its cost.

Another idea that serves as an impediment to good education is that the pupils are not to be made to exert themselves. They are to be amused; this being, of course, the bait used to attract their attention. I contend that education should be a pleasure, not an amusement. Pupils have the greatest real interest in those things about which they can or are forced to think. It is thinking about a subject that makes it interesting. Amusement alone is surely a sedative to mental activity. Rigorous exertion is the drill necessary for proper training. We all recognize that for the development of muscles. The same holds true for the mind.

If mental training and development are the fundamental purposes of education and the acquisition of a memorized body of facts useful in everyday life is also of importance, in what way does the subject of chemistry serve these purposes? Chemistry is the science that deals with all the material of the universe, its properties, and interconversions. It is not, as the layman is apt to believe, just a body of descriptive facts. It is the collection of ways of thinking about matter. It embraces natural philosophy and contains all of the everyday matter-of-fact materialistic reasoning. It is of vital importance for any real culture. It is at the foundation of modern thought, material comforts and advancement, and, in general, our entire civilization. A knowledge of its everyday facts is important for general education, but training in its methods of thought is vital. In the two previous symposia of this series we have discussed at length the values of a knowledge of the subject for general education and its unique importance and value in training the intellect and the development of culture. It is not our purpose at the present time to dwell any further on these. We will assume that they are both recognized and appreciated.

It is necessary, however, that we establish our goal toward which we wish to strive in teaching the subject on the secondary-school and junior-college levels before we consider the teacher. To meet the basic function of education our chief goal is to develop in the pupils a sound, usable, logical, and consistent method of thinking about the stuff and substance of our material universe. We should aim to train our pupils in analytical reasoning, in clear thinking and clear expression, and in a usable natural philosophy. We should endeavor to substitute in them sound reasoning about nature and its materials for superstition, emotional reactions, and traditional ideas. Our next aim should be to utilize the subject for its cultural values, to develop an aesthetic appreciation for nature and its substances and also for the creations man has produced from them. Finally, we must instil in the pupils a certain body of chemical facts about common substances and their transformations.

What would be the ideal teacher to accomplish these aims? He should have all those personal qualities which are desired in a teacher at this educational level for all subjects. He must be mentally alert and trained to think originally and clearly. He must be active and vivacious, as he is dealing with students of an age when they are active and vivacious. He must have a natural and developed interest in people, particularly young people, and must understand their reactions and emotions. He should be aggressive and dynamic. He must have a love of the good and beautiful and have a keen and highly developed aesthetic appreciation for the works of man and nature. Emphatically, he must know his own subject. His knowledge in his own field must be infinitely more than can be obtained by reading one or two textbooks. He must be sufficiently trained in it to think in terms of it, to actually use it. He must be sufficiently interested in it to keep abreast of its current developments at all times and have a great enough

liking for it to do this on his own initiative and because of his own desires. He must understand and appreciate the relationships of his subject to all fields of knowledge.

As high-school teachers frequently must teach more than one subject, the teacher must be sufficiently prepared in other subjects to teach them as well. This is not an insurmountable difficulty, as the subjects naturally group themselves together; and an adequate preparation in one subject necessitates a considerable amount of work in kindred subjects, so that this would either constitute an adequate preparation in them, or very little additional preparation would suffice. For example, an adequate preparation in chemistry would require sufficient physics so that the prospective teacher would either be qualified for teaching physics or would be if he took a little additional work in physics. Also, as our prospective chemistry teacher would be required to know mathematics, perhaps through calculus, the same situation would hold for qualifying to teach mathematics. He may have paralleled his preparation with sufficient work in the biological or earth sciences and be qualified in them also.

As our ideal teacher must be a person of considerable breadth and possess a keen observational ability, by the time he is employed as a teacher he will have seen and appreciated enough of the workings of the world of things about him, human activities as well as material processes, so that he can enter into the matters of administration and organization in which the high-school teacher is so frequently called upon to take part. As intelligence and ability are more important for them than detailed knowledge, a great amount of detailed instruction along these lines should not be necessary.

As all subjects are transmitted through the medium of language, our ideal teacher must be one who not only understands and can use the native language of his pupils in a powerful, dignified manner but who also appreciates the beauties of its literature. He must be able to completely and thoroughly understand every sentence written or spoken and be able to write or speak exactly and clearly. One of the greatest difficulties of our present students is the vagueness of their language, which is probably a reflection of the indefiniteness of the language of their teachers. So few can hear or read a sentence and know exactly what it means, and fewer still can express themselves in a precise and definite manner.

In addition to the foregoing qualifications the ideal chemistry teacher should have been adequately trained in the underlying philosophy of his science and be able to think of the world, its materials and events, in terms of this. He must have acquired enough of the facts of both inorganic and organic substances to have an equipment of knowledge which he can evoke in making use of his knowledge in everyday problems. He must be trained to do this; merely knowing the facts is not sufficient, as his duty is to train his pupils to think as well as to know. He must have acquired sufficient technical skill to perform demonstration experiments and assist his pupils in their laboratory work. Surely an adequate preparation must involve more than attendance at one or two lecture courses in the science.

Having now set up the ideal for our chemistry teacher, let us see how we may approach this goal. The first question is the proper selection of young people with native capacities for teaching. At the present time there is no such selection. Anyone may elect to go to a teachers' college or take the course in education at a university. After students once enrol, there is very little, if any, weeding out of the less competent. The situation is even worse than this. Frequently, students that cannot make the grade in other departments drift into the course in education, or they may leave the university and enrol in a teachers' college. Far too often our less able students in chemistry decide to become high-school teachers of the subject. This is unquestionably a very serious situation. Education is so vitally important for our civilization that we should have the most able for our teaching staffs. Schools of medicine at the present time are very careful of the selection of prospective physicians. They admit only the best of those that desire to study medicine and then ruthlessly weed out those that they find inadequately qualified. Education is surely as important as medicine, and as rigorous methods of selection for its workers should be employed. Schools of education and teachers' colleges should restrict their enrolment to only the better students and then drop those that show little promise. Their standards and requirements should be high enough to both eliminate the weaker students and discourage weak students from other fields from enrolling in their courses.

No student should be permitted to attempt to prepare himself for teaching chemistry, who has not shown a marked liking for and ability in it and other sciences and mathematics. This can be determined from the high-school and college records. He should also have shown that he is mentally alert and manually skilled. If he has not been able to rank scholastically in the higher levels during his schooling he should not be allowed to become a teacher, particularly in subjects in which he has a low scholastic record.

In what way should this human material, which we have now selected, be trained for the profession? We must be careful not to fall into the mistakes that the medical, legal, and engineering professions made some time past but are now correcting. This is the difficulty of too early specialization. It was finally realized that lawyers and physicians were trained in their specialty but were not educated individuals, and now schools of law and medicine require some general education before specialization. Our schools of education seem to be tending toward this error, which could be corrected by giving instruction in the technic of teaching only to those who have completed the major portion of their education. As a teacher should by all means be a person to whom the people, in general, should look to and respect as an educated, intelligent individual, his education must not be so professional that it restricts his point of view.

Let us assume we are to outline minimum requirements for a four-year college course for our prospective teacher. From my point of view at least two years of college English, mathematics through calculus, two years of college physics, and three years of college chemistry, including general chemistry, theoretical chemistry, and descriptive inorganic and organic chemistry should be required. The courses in chemistry and physics should include laboratory work. Any requirements in courses in professional education should be restricted to the fourth year.

Probably more important than the particular courses taken is the quality of the teachers giving them. The best training in teaching methods that a prospective teacher can have is the example of stimulating teaching that he receives. It seems to me that if a person is fortunate enough to have one or two superior teachers during the course of his schooling, he has acquired an education and this chiefly from the one or two teachers. Some of you can probably recall such teachers in your education. It seems that the mind, once awakened to active thinking, finds food for thought itself thereafter. What products our educational system could turn out, if all teachers were as good as these few! If you will analyze the reason that these teachers are exceptional, you will find that it is because they possess active thinking brains and by example and drill can stimulate the pupils. It is not their technic in the light of standardized methods that is the cause of their efficiency. If there were any standardized technics of teaching other than requiring the students to train their minds by strenuous drill and these could be imparted to prospective teachers, we should have succeeded in discovering the Royal Road to Learning.

The old Greek civilization has furnished us with a large-scale experiment in education and teacher-training. No line of reasoning either on the basis of natural law or of probability would lend support to the conclusion that the intellectual capacity in Greece at that time averaged any higher than it does today or at any other time. Yet from a population not greater than that contained in one of our medium-sized cities, a large number of men of such powerful intellectual ability were produced that their works have lived through the ages. Their sum of intellectual production was vastly greater than that produced from any population of similar size before or since. History has shown that each man of powerful intellect was the student of some great man, and in turn some of his students rose to prominence. Our conclusion must be that these men were great teachers and became so because they were stimulated to mental activity and well trained by their teachers. It must be that these men followed the basic principles of education in that the training of the intellect is its chief duty, and that it requires a person having an active and trained mind to do this. These were great teachers and they produced great students—the mark of a great teacher. They became great teachers by having their minds trained in some particular subject. This was a great educational experiment; the results were striking and definite, and from them we should learn a great lesson. It does seem that some of the modern tendencies in education are contrary to the conclusions that must be drawn from this experiment. I could cite a sequence of great teachers in a certain subject in this country; but as the chain is not yet broken and many of the people involved are alive, all I can say about it is that the lesson learned from the Greek education is just as true in this country today.

The example of the Greek civilization cited above demonstrates another important fact. This is that without any more time spent on education than at present our people can obtain much greater values, provided they are supplied with great teachers. Our native faculties are not nearly as highly trained as they could be or should be. This fact, I believe, can be and has been repeatedly demonstrated. This should be food for thought for every teacher and every parent. Our great thinkers of today have probably no greater native mental equipment than that with which large numbers of our people are born. It may be that they are great thinkers because somewhere in their schooling some teacher stimulated their mental activity, or it may even be that the cause lies in a rebellious nature that could not be regimented by our educational system, and the mind trained itself in spite of the system. At any rate, our people can have and should demand greater values in mental training from the time and money spent on education.

As indicated in the American Chemical Society report previously cited, there is a general opinion that the quality of high-school teaching has declined and, perhaps, is declining. This is also indicated by the fact that the texts for the first college courses in such subjects as physics and mathematics are being forced to become easier and contain less and less in content and rigor. This decline has paralleled three things, which may be the contributing causes: the legal requirements in courses in education for teachers, the theory that mental training in one subject is without value in another, and the educational point of view that the pupils are not to be rigorously drilled, but are to be stimulated to activity by amusement.

There is a considerable difference of opinion as to the educational value of mathematics. Although it is beyond the purpose of the symposium to discuss this topic, nevertheless, I may assert the opinion, which I believe will be shared by my fellow scientists, that mathematics is a great subject for mental training, that it should be stressed much more in the high schools than it is at present, and that the present trend is toward less, rather than more, rigorous mathematics in secondary schools.

Even if we should be able to select prospective teachers carefully and prepare them adequately for their work, we must make the profession sufficiently attractive so that the best qualified will elect it as their life work. The financial compensation, the general recognition of the importance and high standing of the work, and the opportunities for advancement must be as

great as in any other profession requiring equivalent abilities and training. At present this is not the case. It must be made so, if we are to improve our secondary school education.

Assuming that we can make the profession sufficiently attractive there is still another problem of almost vital importance, for which a solution must be found for the best interests of the profession, the public at large, and our civilization. This is to provide enough incentive for high quality teaching in the way of advancement in salary and position to stimulate the teacher to continued improvement. This advancement must be on the basis of the quality of his work. The profession must be made competitive, with the more efficient rising to the top, the less sinking to the bottom, and the least being eliminated. We have no adequate measure of the quality of the teacher's work. His advancement in salary depends upon such things as years of service, the personal opinion or bias of some administrative officer, or on political whims. Sometimes it may depend upon his taking additional courses, irrespective of whether these are in his own subject, what their content may be, or whether taking them would improve the quality of his work. None of these things should be permitted to govern his salary or position. These should be based upon his efficiency and upon this alone.

The quantitative measurement of the secondary-school teacher's efficiency is no easy task; but, nevertheless, it is not an impossible one. The registrars in our universities know the quality of the high schools from which their students come, and frequently either they or the department heads can rate the quality of the teaching of the different subjects in these schools. Where a high school rates highly, the teachers in that subject are the ones to whom the credit is due and should be given.

The only thing that should be taken into consideration in the rating of teachers is the net improvement in the knowledge and thinking ability of the students, for this is the basic purpose of education. To measure this quantitatively is difficult, but perhaps it can be done. There are large numbers of teachers in every subject throughout the country. Examinations could be prepared in every subject, and these given to all the students taking this course in a state or nation. These examinations must be carefully constructed so that high ratings on them could not be obtained by a student having only memorized facts at his command. The questions must be made in such a way that the facts are used in some thinking process depending on the nature of the subject. Essay questions, except perhaps in languages, and true and false or similar types of questions would naturally not be included in such examinations. The pupils' grades in these examinations would be the basis upon which the teachers would be rated. After records for a number of years had accumulated, a fairly quantitative method of rating the teachers could be evolved. Of course, in subjects that extend through a number of years the teacher's rating must depend upon the net improvement of his students and not on their grades in one examination alone. Even for subjects which one teacher handles exclusively, the general quality of his students as determined by their previous examinations in all subjects should be taken into consideration. Surely these examinations must be neither prepared nor graded by the teachers involved, but by some impersonal and unbiased group.

After having developed a technic for evaluating the efficiency of the teachers, we should then compensate them exclusively on this basis. It could be so arranged that communities desiring the best teachers could obtain them by offering the highest salaries, and those not anxious for the best education for their young people could get what quality they were content to pay for. They would lose their better teachers to towns seeking the higher rating teachers. Such a procedure would provide an incentive for the teacher to improve his work, place the profession on a proper competitive basis both on the part of the communities seeking the best teachers and for the teachers seeking the best positions, provide a means for advancement, and raise the salary level for those deserving it.

What has all this to do with the quality of the secondary-school teaching of chemistry and the preparation of chemistry teachers? First, if we criticize the present methods and trends, we shall be asked immediately for constructive suggestions. We are much too interested in the subject to make only damaging criticisms. Second, it is probably impossible to isolate the problem of the quality of secondary-school chemistry teaching and the preparation of its teachers from the larger questions of both primary- and secondary-school education and the general subject of selection, preparation, and the quality of teachers. Third, as we are concerned with the quality of the high-school teaching of chemistry, we believe that this could be improved by an improvement of the preparation of the teachers in chemistry and also in subjects like physics and mathematics. Fourth, as we desire to raise the educational standards on the college level, we are interested in the secondary-school training of the students, not only in chemistry, but also in English, mathematics, and other subjects.

As to suggestions in regard to the preparation of high-school teachers of chemistry, which are more immediately practicable, I should like again to quote from the report of the committee on High School Teaching of the American Chemical Society, which was adopted by the Society.

"The committee recommends that the American Chemical Society go on record as endorsing the following views originally recommended by the Committee on Required Courses in Education of the American Association of University Professors.

"1. There is no reliable evidence that professional requirements have resulted in an improvement in secondary instruction at all commensurate with the amount of the requirements.

"2. A considerable lowering in the requirements would result in economy, and would not lessen the

effectiveness of instruction in the high school. There is, in fact, reason to believe that, on the average, teaching would be improved through a possible increased knowledge on the part of the teacher, of the subjects he teaches, or of related subjects.

"3. A maximum of twelve semester hours is ample to cover that part of professional training which can be regarded as essential for the beginning teacher who has a bachelor's degree from a standard college or university, and who qualifies for teaching an academic subject. The training should involve practice teaching and methods, the methods course being closely integrated with the practice teaching. Courses in psychology or educational psychology, when these are required, should be counted toward the requirement.

"In addition to these recommendations your committee further recommends:

"4. That the American Chemical Society go on record as advising that the sequence in required 'professional' or 'teacher-training' courses be so arranged that the entire sequence can be taken by advanced science students within one academic year.

"5. That the American Chemical Society pronounce itself as opposed to 'unrestricted certification' of high-school teachers, by means of which teachers are at present teaching subject matter courses in which they themselves have had no previous training and in favor of 'restricted certification' whereby only those persons who have had a specified amount of collegiate training in a particular subject-matter field will be permitted to teach in that subject-matter field in high schools.

"6. That the American Chemical Society go on record as emphatically asserting its belief that a prospective instructor should be required to present evidence of an adequate background in subject matter courses before he or she is eligible for assignment to teach in that particular subject matter field in high schools.

"7. That the American Chemical Society express its belief that for such 'restricted certification' the minimum amount of collegiate course credit in the specific subject matter field should not be less than the minimum amount of course credit which is required in 'professional' or 'teacher-training' courses, and that for certification to teach chemistry a minimum requirement of courses through organic chemistry (because of its importance in life processes) is essential."

For the best interests of instruction an additional requirement would be desirable specifying that in the subjects to which the prospective teacher is certified the quality of the work done must be high and that merely obtaining passing grades would not suffice. This could be accomplished by only certifying teachers who can obtain recommendations from the academic departments of these subjects in recognized institutions, to the effect that the grades obtained in the subjects have been above average. Medical schools place particular emphasis on the quality of the work done in subjects in which they are particularly interested, such as the sciences, in evaluating a candidate's credentials for admission.

To summarize the point of view that I am taking in regard to secondary-school teaching and the preparation of chemistry teachers for it, I wish to re-state that we must be led to the conviction that the basic purpose of education is the training and development of native mental faculties as well as the precise acquisition of facts. One not involved in the details of high-school and junior-college teaching is apt to have the opinion that this main function has been lost sight of in a maze of lesser values, with the result of a diminution of the quality of our general education.

In order to stimulate and keep mentally active the minds of the pupils it is essential that the teachers be mentally alert and have trained and developed minds. To obtain and retain a teaching staff of this kind it is necessary to attract prospective teachers from among the better of our youths, to select those with the desired qualifications, to prepare them by a sufficient amount of rigorous training in their chosen subjects, and last, but by no means least, to provide adequate stimulation by means of possible advancement and salary for those whose work is the most efficient, as well as a means of eliminating the least efficient.

If we should do this, it is my opinion that the question of teaching methods will take care of itself. The stimulation of ambition will tend to encourage each teacher to seek out the methods best suited to his subject, personality, and pupils.

The importance of the secondary-school teacher being able to take part in the school administration, extra-curricular activities, determination of policy, community contacts, etc., cannot be denied. However, if we have selected high quality individuals for our teachers and have given them a good basic education, we need concern ourselves very little in regard to their ability to do these things and need to supply them with only a small amount of detailed instruction about them in their training. If there seems to be a great need for this at present, it may be because of the general weakness of the selection of teachers and the lack of rigor in mental training in their preparation. A high quality individual well trained will automatically be accepted as a leader in the community and will be able to take part in those other activities without undue difficulty. To attempt to correct some of the present difficulties by insisting on more instruction for prospective teachers in the details of these things, seems to me very similar to attempting to cure a disease by treating the symptoms.

With these points of view I believe the chemists will be in general agreement. We are interested in a high quality of secondary-school teaching both in chemistry and in other subjects and believe that the best method of obtaining these results is to insist upon a rigorous schooling of the teachers in a sound curriculum containing an ample amount of chemistry. We also believe that special educational subjects are of secondary importance for the main purpose of the schools and that requirements in these should be reduced to a minimum.

PROJECTION *and* FILING *of* MICROPHOTOGRAPHIC REPRODUCTIONS

JAMES A. AUSTIN AND HAROLD P. BROWN

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MICROPHOTOGRAPHIC duplications of scientific literature on 35-mm. film have been made available to research workers by Science Service, under the name Bibliofilm Service,[1] at a remarkably reasonable price. Such duplications may be readily enlarged to a convenient size by means of an ordinary projection lantern. It is advisable to employ a water cell or heat-absorbing glass during prolonged projection to avoid curling or warping of the film. There is no danger of burning the film.

Two methods of preparing the film for projection have been employed. In the first method, which is particularly applicable to short strips, the films were cut into segments which were mounted individually. In the second method, which is especially suitable for long strips, the film strip was kept intact and projected with the assistance of a film holder as described below. Most duplicates of recent literature are less than twenty pages per article and can be handled conveniently by the first method.

Bibliofilm Service photographs double pages on a single exposure. Sufficient space is left to allow the film to be cut between these exposures, thus yielding separate two-page units. These units are mounted between two-ply Bristol cardboards, which are 67 mm. wide and 100 mm. long with a window 22 mm. wide and 30 mm. long in the center. A good grade of liquid glue is applied over the sprocket holes of the film on the concave side. The film is then placed over the window of one of the cards so that all of the printed matter is visible. It has been found convenient to carry out the entire procedure on a glass plate dimly lighted from beneath. The film is pressed against the card so that excess glue is removed and the film thoroughly flattened. Glue is applied on all four sides of the film and along the edges of the card. The second card is put in place so that all printed matter on the film is clearly visible and pressed until a firm seal is obtained. The finished mount is allowed to dry while pressure is applied to prevent curling. The mounts are marked to indicate the position in which they should be inserted in the slide holder for projection and they may be projected by inserting them between two glass plates such as are ordinarily used in making glass slides. These plates are separated by two pieces of cardboard 63 mm. wide, 100 mm. long, and 0.2 mm. thick, which are glued, one at each of the long sides of the slide, so that the mounts are held firmly in place. The two glass slides are held together by tape along the edge of the cardboard separator. Only one such mount holder is necessary but it is sometimes convenient to have several.

Films mounted as described can be stored in an ordinary filing cabinet. Plenty of space is available on the card for notation of identifying data such as the title of the article, journal, book, author, etc. Such a set of cards can be filed according to the Dewey System, Library of Congress Classification, or other systems more suitable to a particular need.

In some instances, especially in the case of long articles, it is more convenient to project and file the microphotographs as a continuous strip. This may be done by the following method. Two glass slide plates are held apart by a cardboard separator 0.08 mm. thick, 23 mm. wide, and 100 mm. long and the plates taped together along the long edge. A window 37 mm. wide and the entire length of the slide is thus left open. This window is just large enough to permit the film strip to be drawn through without binding. This unit is then set in a wooden frame which is made just large enough to occupy the space usually taken by the slide holder of an ordinary projection lantern. This frame is provided with a slit opening on the short sides to allow introduction of the film and a window 25 mm. wide and 77 mm. long in the center parallel to the long axis, thus allowing the clear vision of all printed matter but screening out the sprocket holes of the film. This window allows the projection of two exposures or four printed pages at a time.

If desired, small removable spindles may be fastened to the wooden frame employed in the projector to facilitate the holding and rolling of the films.

The projected microphotographs show white markings on a black background and are therefore best observed in a darkened room. The projection may be made large enough to be read simultaneously by several persons.

[1] DAVIS, W., *Science*, 83, 402–4 (1936).

A SURVEY *of* INFRA-RED SPECTROSCOPY

Part II. The Origin, Appearance, and Interpretation of Infra-Red Spectra

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THE SPECTRA OF GASES

The absorption spectra of molecules in the gaseous state may be divided, very roughly, into three classes, according to their wave-length region. The first is a complex series of bands occurring in the ultra-violet region of the spectrum and extending up into the visible; the second, a much simpler series of analogous bands in the "near" infra-red, $\lambda < 20\mu$, and sometimes extending into the red end of the visible spectrum; and the third, which is the simplest of all, a number of rather simple absorption maxima which extend as far in the infra-red as measurements have been made.

Evidently any molecule is capable of three types of internal motion: motions of the electrons surrounding the nuclei, motions of the nuclei relative to one another, and a rotation of the molecule as a whole. Since the energies associated with these three types of motion are of entirely different magnitudes, and it is possible to estimate the magnitude for each type, it is not hard to correlate each of the three spectral regions with one type of molecular motion. Thus, we say that the ultra-violet spectra are due to electronic motions, the near infra-red to nuclear vibrations, and the far infra-red to molecular rotations. These divisions, of course, are not sharp, and there is some overlapping of regions.

We are concerned here only with the infra-red spectra and will neglect entirely the effect of electronic motion. This may be done for the following reason: electronic motions, as we have seen, are associated with very high energies, and the electrons are very light particles compared with nuclei; hence, their motions will be fast compared with those of the nuclei and the electrons will go through many cycles while the nuclei are performing one. The electronic effects evidently will average out, to a close approximation, over one nuclear cycle and we may consider each type of motion separately.

The nuclear vibration and molecular rotation spectra, which we shall refer to hereafter simply as "vibration" and "rotation" spectra, are quite different cases, however. Here we are no longer considering the motion of light particles against very heavy ones, and the energies concerned are not vastly different. We shall see later, though, that we are permitted usually, to a good approximation, to consider the rotation apart from the vibration, and *vice versa*.

The question which now arises, after determining the origin of these absorptions, is as to the conditions under which they may appear. Not all molecules have far infra-red spectra, and some few have no absorption even in the near infra-red. This question, fortunately, is readily answered for the general case, though the application to specific molecules is not always so easy. It is well known from electromagnetic theory that radiation may be absorbed or emitted only by a system whose electrical configuration, relative to a point in space, is changing. This means that a vibration of a molecule will result in the absorption of radiation only when the electric moment of the molecule changes in the course of that vibration. Similarly, a molecular rotation will result in absorption only if the molecule is possessed of a permanent electric moment. As an example, in the HCl molecule the two atoms are bound together by a so-called "ionic" bond; that is, the electronic distribution is such that the charge of the H atom is positive, and that of the Cl atom negative. This molecule has, then, a permanent dipole moment and, experimentally, it exhibits strong absorption regions in the far infra-red. Furthermore, when the two atoms vibrate relative to one another the distance changes and we have an effective change in dipole strength; and experiments show that HCl has several absorption maxima in the near infra-red. O_2, on the other hand, is a symmetrical molecule, and the bond is of the "covalent" type; that is, the electrons are shared equally by the two atoms. In this case neither atom is charged, there is no dipole, and hence no pure rotation spectrum. Furthermore, as the system vibrates it remains electrically neutral and we have no vibration spectrum.

Now, in order to explain why the absorption occurs in definite regions, or "bands," instead of being spread over the whole spectrum, consider first the vibrational

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motion. A molecule, consisting of s particles, has $3s$ degrees of freedom. Three of these degrees, however, are to be associated with translation of the molecule as a whole, and, for the non-linear case, three more are associated with rotation of the molecule about its three principal axes. For the linear case, of course, only two degrees of freedom may be associated with rotation, but we will consider this special case later. This leaves, for the general case, $3s-6$ degrees of freedom to be associated with internal vibrations of the molecule. Experience has shown that the potential energy for vibration of such a system may usually be closely approximated by the assumption of Hooke's law forces between those atoms known, from chemical data, to be bonded together. The restoring force, as the bond is stretched, is assumed to be proportional to the elongation. Using a potential function based upon this assumption, the classical equations of motion may be solved and we find that, actually, the molecule possesses $3s-6$ "normal vibrations," that is, there are $3s-6$ different ways in which the system may vibrate without either translational or rotational energy being imparted to the molecule by the atomic motions. The form of each normal vibration is determined by the symmetry of the molecule and by the particular potential function used. With each of these normal modes there is associated a particular frequency, and hence a particular energy. A quantum mechanical treatment shows that the molecule must exist in a state which is either one of these fundamental energy states or a multiple or combination of them. Furthermore, energy in the form of radiation may be absorbed or emitted only when the molecule jumps from one of these permitted states to another, and the amount of this energy is exactly equal to the energy difference between the states. To use the language introduced by Bohr, if we consider a transition between two states, a and b, of energies W_a and W_b, the energy of the absorbed quantum of radiation is $W = W_b - W_a$. The energy of the quantum is related to its frequency ν by the expression $W = h\nu$, where h is Planck's constant.

Let us next consider the rotational energy of a molecule. The problem has been treated quantum mechanically by Casimir, Kramers and Ittman, Wang, and many others, and the general results are that the rotational energy, too, is "quantized"; that is, the molecule may exist only in certain definite rotational energy levels, and radiation quanta are absorbed or emitted only as a result of a transition between them. Quantum mechanics also shows that transitions may not occur between any two arbitrarily selected states, but depend on certain definite "selection rules." These, however, together with the vibrational selection rules, will be considered in later sections when specific molecules are discussed in greater detail.

The general characteristics of infra-red bands may be summed up as follows. The far infra-red absorptions are due to permitted transitions between allowed rotational energy levels, giving rise to a discontinuous spectrum. In the near infra-red, transitions between allowed vibrational levels, during the course of which the rotational level remains unchanged, result in absorptions whose frequencies are measures of the energy differences between the vibrational states. In general, however, as is shown by quantum mechanics, the rotational and vibrational levels change simultaneously. Since the rotational energy differences are small compared with the vibrational, this gives rise to a cluster of "lines" in the absorption spectrum, the center of which corresponds to the "pure vibration" transition.

The problems of this section may perhaps be demonstrated more clearly by the consideration of a number of specific examples of various types of molecules, and this will be done in the next few sections.

DIATOMIC MOLECULES

Obviously a molecule consisting of only two atoms is capable of two motions: one a vibration along the connecting bond, and the other a rotation about the center of mass. A quantum mechanical treatment of the vibration, assuming Hooke's law forces, yields the result that the permitted vibrational energy states W_v are given by the formula

$$W_v = h\nu_0(n + 1/2) \qquad n = 0, 1, 2, \ldots\ldots$$

Here ν_0 is known as the fundamental vibration frequency and n is a positive integer called the "quantum number." In a transition between two of these permitted energy levels the selection rule for the foregoing case of the simple harmonic oscillator is $\Delta n = \pm 1$. Actually the force function is not as simple as the one assumed above and so, although the above formula usually gives a fair approximation to the values of the energy levels, other transitions for which Δn is greater than 1 may appear. Since practically all bands appearing in infra-red absorption spectra are the result of transitions from the ground level ($n = 0$) to some higher state, we may write for the energies of these bands $W = W_n - W_0 = nh\nu_0$. Since $W = h\nu$, we see that the frequency of light absorbed at any band is a multiple of the fundamental frequency ν_0. The absorption spectrum of a diatomic gas should, according to this theory, consist of a series of equally spaced bands, at the frequencies ν_0, $2\nu_0$, $3\nu_0$, etc. The experimental fact is, however, that the spacing between bands is not constant but tends to decrease slightly with increasing n. This may be taken care of by considering a more complex force function than the one given, which leads to the expression

$$W_V = h\omega_e(n + 1/2) + hx\omega_e(n + 1/2)^2$$

where ω_e and $x\omega_e$ are constants which may be determined from the observed data, and then applied in the equation to determine the frequencies of other bands.

The rotational energy of a diatomic molecule is given by the expression

$$W_R = \frac{h^2}{8\pi^2 I} J(J+1)$$

Here, I is the moment of inertia of the molecule, and J

is the so-called rotational quantum number which may take on values of 0, 1, 2, ... The selection rule is $\Delta J = \pm 1$. It is readily seen then that the pure rotation spectrum consists of a number of equally spaced absorption lines of energy $W = (h^2/4\pi^2 I)(J + 1)$ and with a spacing $\Delta\nu = h^2/4\pi^2 I$.

The fine structure of the near infra-red vibration-rotation bands is given by those transitions in which

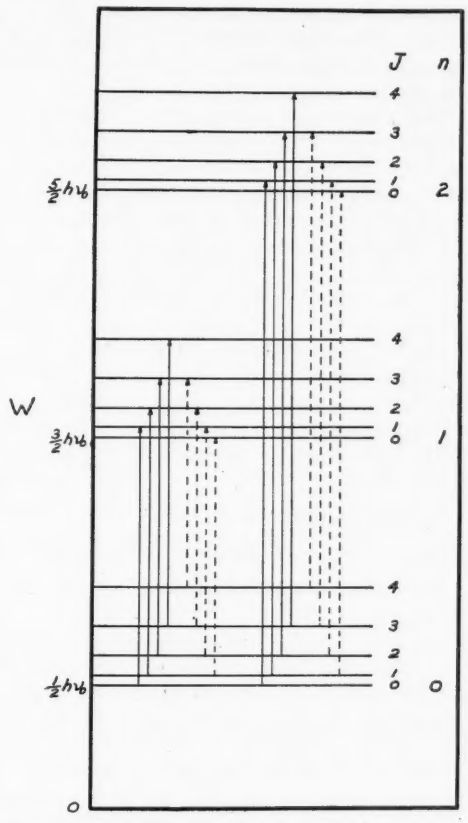

FIGURE 1.—SCHEMATIC DIAGRAM OF THE ROTATION-VIBRATION LEVELS OF A DIATOMIC MOLECULE, SHOWING PERMITTED TRANSITIONS. DOTTED LINES INDICATE *P*-BRANCH TRANSITIONS

both the vibrational and rotational quantum numbers change. Since the rotational energy is small compared with the vibrational energy the effect is to give, on each side of every frequency corresponding to a vibrational transition, a set of lines which corresponds to the pure rotation lines, and which possesses the same spacing. Those on the red side of the band center correspond to transitions for which $\Delta J = -1$ while those on the violet side are for $\Delta J = 1$. Since $\Delta J = 0$ is forbidden there is a missing line at the center. These two wings on either side of the band center are known as the negative, or *P* branch, and the positive, or *R* branch.

Figure 1 shows, plotted against energy as the ordinate, the first three vibrational levels of a diatomic molecule, with a few of the low rotational levels superimposed on each. The permitted transitions are designated by vertical lines.

To complete this discussion, it should be mentioned that in the near infra-red bands, vibration and rotation are not completely independent. Their interaction tends to make the fine structure lines converge on one side of the center and diverge on the other. This may be qualitatively explained as resulting from the distortion of the molecule in the higher vibrational state. In general, the effect of the higher vibrational energy will be to stretch the molecule slightly, thereby increasing the moment of inertia in the upper state and decreasing the rotational spacing. It may be seen, by an examination of the energy level diagram, that this would lead to the observed effect.

An examination of the fine structure lines of an absorption band shows that the intensities of the various lines vary widely over the band. Going out from the band center on either side, the first lines are rather weak, but successive ones grow stronger and stronger until a maximum is reached. After this, the intensity decreases toward the wings, and finally vanishes. This gives rise to the "doublet" effect, first explained by Bjerrum, of two maxima with a minimum in the center, shown by a diatomic molecule band when viewed under low resolution. These intensity variations of the lines within a single band are due principally to the number of molecules of the gas occupying each of the initial rotational levels. This population depends, for the most part, on two factors—first, the ordinary thermal distribution, which decreases exponentially with the rotational energy; and, second, on a degeneracy factor which increases linearly with J. Thus, as the J value for the lower state increases to give the successive lines in the band the first effect is that the degeneracy factor increases rapidly, giving rise to increasing intensity. Soon, however, the exponential factor becomes important and quickly pulls the intensity down to zero. For the $(J + 1)st$ line in the R branch the intensity is given by

$$I = C(2J + 1)e^{-\frac{E_j}{kT}}$$

while for the Jth line of the P branch it is

$$I = C(2J - 1)e^{-\frac{E_j}{kT}}$$

Here C is a constant over a given band, E_j is the energy of the Jth rotational state, k is the Boltzmann constant, and T is the absolute temperature.

A determination, such as may be made with a low dispersion spectrometer, of the doublet separation of

any one of these bands leads to a rough value of the moment of inertia I. The equation is

$$\Delta\nu = \frac{1}{2\pi}\sqrt{\frac{kT}{I}}$$

where $\Delta\nu$ is the frequency difference between the two maxima.

HYDROGEN CHLORIDE

To illustrate the formulas set down in the previous part, we may consider, as an example, the HCl molecule. This is an asymmetric diatomic molecule and hence exhibits both near and far infra-red absorption spectra.

Low dispersion investigations with a rocksalt prism spectrometer showed in the near infra-red a very strong absorption at 3.46μ, a weaker one at 1.76μ, and another,

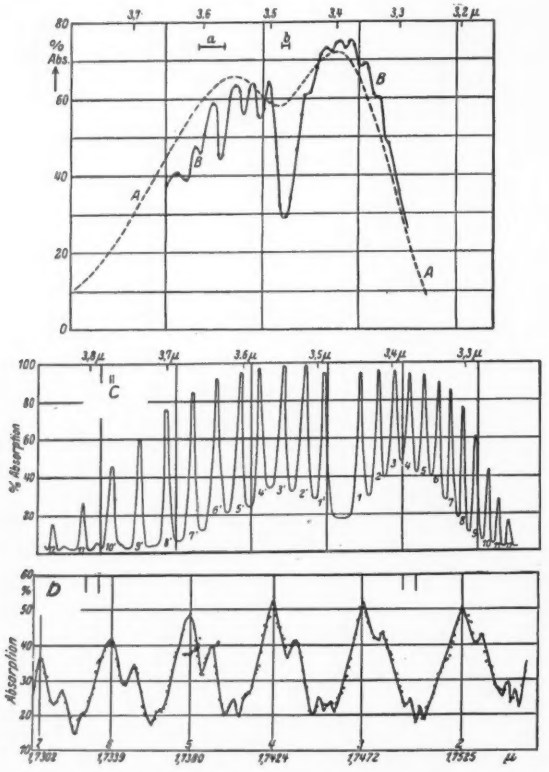

FIGURE 2.—THIS FIGURE SHOWS SUCCESSIVE STEPS IN THE INVESTIGATION OF THE 3.46μ HCl FUNDAMENTAL. CURVE A WAS OBTAINED BY BURMEISTER IN 1913, USING A FLUORITE PRISM INSTRUMENT; B BY VON BAHR IN 1913 WITH A QUARTZ PRISM; AND C, BY IMES IN 1919, USING A GRATING SPECTROMETER. CURVE D SHOWS A PORTION OF THE 1.76μ OVERTONE AS OBTAINED BY HETTNER AND BÖHME IN 1931

still weaker, at 1.19 μ. These absorption regions, when examined closely, had a "doublet" structure, two regions of high absorption with one of low absorption between. The 3.46μ band, when investigated later with an echelette grating, was broken up into a series of almost equally spaced lines with a missing line at the band center. Still later, even more careful examination showed that between the strong lines there was a series of fainter ones, with about the same spacing. These successive steps in the development are shown in Figure 2. Since we shall not concern ourselves particularly with the faint lines, it may be mentioned here that they appear as a result of the fact that chlorine is not a pure atomic species, but is a mixture of two isotopes of mass 35 and 37. The strong series is due to HCl molecules containing the comparatively more abundant isotope of mass 35, and the other to those containing Cl^{37}.

The bands mentioned above are to be correlated with the predicted vibrational structure in the following way: the band at 3.46μ is the fundamental vibration, that at 1.76μ the "first harmonic," and that at 1.19μ the "second harmonic." That is, the 3.46μ band results from a transition from the ground level to the first vibrational level; the 1.76μ band, from the ground level to the second; and the 1.19μ band, from the ground level to the third permitted vibrational level. Recent and more accurate measurements show that the centers of these three bands fall at 2885.9, 5668.0, and 8403.0 cm.$^{-1}$, respectively.* These three frequencies are not exactly in the ratio 1:2:3, but may be fitted to a quadratic formula of the type mentioned above, but which we will write here:

$$\bar{\nu} = \omega_0 n + x\omega_0 n^2$$

The values of the constants are

$$\omega_0 = 2937.8 \text{ cm.}^{-1}$$
$$x\omega_0 = -51.9 \text{ cm.}^{-1}$$

Let us now examine the fundamental band more closely. The first nineteen lines on each side of the band center have been measured by Colby, Meyer, and Bronk (*1*). As we have seen, the spacing of these lines should give us a measure of the rotational constant $h/4\pi^2 I$ and hence of the moment of inertia, I. The spacing is not constant on both sides of the center, due to interactions of the type mentioned above, but for the present purpose it will suffice to take an average of all the observed spacings and base our calculations on that. This average turns out to be 19.46 cm.$^{-1}$. Using frequencies, instead of energies as above, we may write $\Delta\bar{\nu} = h/4\pi^2 Ic$, and, solving this, $I = 2.84 \times 10^{-40}$ g.-cm.^{2}. This is the moment of inertia of the system, considered as two point particles rotating about their center of mass. For this case, $I = \mu r^2$, where μ is the so-called "reduced mass," $\mu = m_1 m_2/(m_1 + m_2)$ and r is the interatomic distance. Remembering that we are dealing with H of mass 1.008 and Cl of mass 35, and that

* Frequencies are usually given in the literature in "wave numbers," symbol $\bar{\nu}$. The wave number is defined as the reciprocal of the wave-length in cm., and the unit is cm.$^{-1}$. This quantity is proportional to the true frequency, ν, the proportionality factor being c, the velocity of light. The wave number is convenient since it is proportional to the frequency, and hence to the energy, but is still a quantity of a convenient size.

the masses must be divided by Avogadro's number to reduce them to grams, we find $r = 1.33 \times 10^{-8}$ cm. = 1.33 Å. A careful calculation, taking into consideration the convergence of the rotation lines, yields values of $I = 2.649 \times 10^{-40}$ g.-cm.^{2} and $r = 1.281$ Å. So it can be seen that, even with the crude approximations made above, the results obtained are surprisingly good.

There is still another molecular constant which can be calculated from measurements of the vibrational spectrum, namely, the vibration force constant. If we consider our system to be simply an harmonic oscillator, the relation from classical dynamics $\bar{\nu} = 1/2\pi c \sqrt{k/\mu}$ may be applied. Here again μ is the reduced mass, and k is the Hooke's law constant of the oscillator. The result of this calculation is that $k = 4.78 \times 10^5$ dynes/cm., using for $\bar{\nu}$ the above value for the center of the absorption band.

Seven lines in the pure rotation spectrum of HCl have been measured by Czerny (*2*), at wave-lengths between 44 and 120μ. The lowest energy line measured, that at 120μ, resulted from the transition between the rotational level with $J = 3$, and that with $J = 4$. Czerny was unable, with his apparatus, to reach the longer wave-lengths at which the transitions involving $J = 1$ and $J = 2$ would appear. The wave number differences between the seven lines measured were very nearly constant, the average value being 20.49 cm.$^{-1}$. Calculating with this value exactly as before, we obtain $I = 2.70 \times 10^{-40}$ g.-cm.^{2} and $r = 1.29$ Å., in quite good agreement with the values previously obtained from the vibrational spectrum.

Considerable interest has been shown of late in the spectra and properties of compounds in which H of mass 1 has been replaced by its mass 2 isotope. We might investigate the result of this substitution in HCl, and compare the spectra of HCl and DCl. Since the isotopes H and D differ only in nuclear mass, and are identical in electrical configuration, it is not unreasonable to expect that, in a given bond, the interatomic distance and force constant will be unchanged by the substitution. If we return to the formula $\nu = {}^1/_{2\pi} \sqrt{k/\mu}$, we see that the ratio of the two fundamental frequencies should be equal to the inverse ratio of the square roots of the two reduced masses. Carrying out this process, we find a proportionality factor of 0.718. If, then, the fundamental of HCl is at 3.46μ, that of DCl should fall at about 4.82μ. Applying the same reasoning to the moment of inertia ratio, since the rotational spacing of HCl is 20.49 cm.$^{-1}$, that of DCl should be about 10.5 cm.$^{-1}$. These predictions agree very well with the values, 4.79μ and 10.67 cm.$^{-1}$, observed by Hardy, Barker, and Dennison (*3*).

POLYATOMIC MOLECULES

As we have seen above, any non-linear polyatomic molecule of n atoms has $3n-6$ degrees of vibrational freedom. Corresponding to these are $3n-6$ normal modes of vibration, each with a definite vibration frequency determined by the constants of the molecule. Any frequency observed in the near infra-red spectrum of any molecule must either be one of these fundamental frequencies, or a multiple or combination of them. The matter of the complete spectrum of a polyatomic molecule is one of extreme complexity and, as a result, complete and satisfactory solutions of the rotation and vibration problems have been carried out for only a few of the simpler ones. It is none the less possible to make considerable headway in the interpretation of these spectra if a few simplifying assumptions are made.

For this approximate type of treatment we shall consider the molecule as made up of a number of atoms, viewed as point particles, held together by Hooke's law forces. For the stationary molecule, these forces are at equilibrium for some definite spacial configuration of the atoms, and it is about this equilibrium position that the vibrations occur. We shall further assume that the amplitude of the atomic vibrations is small compared with the interatomic distances, and that vibration and rotation may be treated separately.

To each normal mode corresponds a "normal coordinate," which is a linear combination of the $3n-6$ coördinates originally used to describe the system. In discussing the vibrating system it is usually convenient to make the transformation to the $3n-6$ coördinates. The methods used to find the transformation to normal coördinates, and to find the shape and characteristics of the normal modes will not be gone into here. Sometimes the nature of the vibrations may be deduced from an examination of the system; at other times, it is necessary to apply the methods of Lagrangian mechanics, the details of which may be found in Whittaker's "Analytical Dynamics" (*4*) and in Dennison's paper (*5*). The most generally useful and applicable method, particularly for more complicated molecules, is, however, one developed by Wigner (*6*), Wilson (*7*), and others. In this, the symmetry properties of the system are treated by the methods of group theory to yield the forms of the normal vibrations, as well as the relations connecting their frequencies with the physical constants of the system. Since the following discussion is for the most part of a qualitative nature, we shall simply assume this information where necessary. In later sections, where specific examples are discussed, we shall give diagrams of the normal modes for some of the principal molecular types.

The vibrational energy of polyatomic molecules is, of course, "quantized." The energy of any vibrational state is given, to a first approximation, by a series of terms, each of which is similar to the simple expression written down for the diatomic molecule. Thus, for a triatomic molecule with three normal modes

$$W_v = h\nu_1(V_1 + {}^1/_2) + h\nu_2(V_2 + {}^1/_2) + h\nu_3(V_3 + {}^1/_2)$$

Here ν_1, ν_2, ν_3 are the frequencies of the normal modes and V_1, V_2, and V_3, the quantum numbers, are positive integers. To this approximation the frequency of a

band resulting from a transition from the ground state, where all V's are zero, to any excited state is given by

$$\nu = V_1\nu_1 + V_2\nu_2 + V_3\nu_3$$

That is, any band is a sum of the multiples of the frequencies of the fundamental bands. These formulas assume Hooke's law, or harmonic forces, to exist between the atoms, and the degree of anharmonicity present may be gauged by the accuracy with which the experimental data are fitted by the above expression. Usually a much better fit may be obtained by the use of an energy equation which contains, in addition to the above first power terms, terms involving the squares and cross products of the quantum numbers. Such equations will be demonstrated later.

Only those fundamental modes will, of course, be active in the infra-red which give an effective change in the electric moment of the molecule during the progress

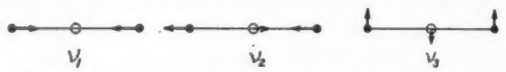

FIGURE 3.—NORMAL MODES OF THE SYMMETRICAL LINEAR TRIATOMIC MOLECULE XY_2

of the vibration. Which of the modes will be accompanied by such changes can usually be readily ascertained from an examination of the vibration form.

The fine structure of the active bands, or, under low resolution, the band envelope, will, of course, depend on the rotational changes which accompany the change in vibration. The molecule will, in general, have angular momentum about each of its three principal axes of inertia, so the fine structure will depend upon the amounts of momentum about each, and upon the way in which the selection rules permit this momentum to change. In general the selection rules depend upon the direction in which the electric moment of the particular vibration involved is changing relative to these principal axes of inertia, so the structure of the various bands may be very complex. Molecules may be divided, however, into only a few general classes, the members of which possess a number of features in common and which have spectra similar in appearance. In discussing the features of vibration-rotation bands in the near infra-red, as well as the features of the pure rotation spectrum, we shall consider each of these classes separately.

Frequently, particularly in the case of highly symmetric molecules, several of the modes are not active in the infra-red. A knowledge of the frequencies of these modes may be highly desirable, both to complete the analysis of the vibrational levels, and to compute molecular constants depending thereon. In these cases, it is necessary to seek other methods of determining fundamental frequencies. Fortunately, a very powerful aid in this direction is found in the Raman effect, discovered in 1928 by Sir C. V. Raman. In these experiments a beam of monochromatic light is shone into a vessel containing the substance to be examined, preferably in the gaseous phase. The light scattered by the material at an angle of 90° with the incident light is examined by means of a spectrograph. It is found that the scattered light contains, in addition to the initial frequency, ν_0, very weak lines whose frequencies differ from ν_0 by definite amounts, characteristic of the substance. These frequency differences, or shifts, correspond exactly with some of the fundamental frequencies of the molecule examined. According to a very simple theory, the molecule in the normal state has absorbed the whole photon of incident light, and then emitted a part of it again, the molecule being left in the first excited vibrational level, and the frequency of the emitted photon differing from that of the incident simply by the frequency of the vibrational state.

The laws determining the conditions under which a fundamental mode may be active in the Raman effect are too complex to be gone into here. Suffice it to say that it is usually those modes in which the symmetry of the original molecule is most nearly retained and therefore are most likely to be inactive in the infra-red, which appear strongly in the Raman effect. Occasionally some mode may not be allowed in either the Raman or infra-red, and, unfortunately, there is as yet no very satisfactory way of determining these frequencies.

LINEAR MOLECULES

As was pointed out in an earlier section, linear molecules have three degrees of freedom to be associated with translation, and, since the moment of inertia about one axis (the axis of figure) is practically zero, we may have only two degrees for rotation, leaving $3n-5$ for vibration. This would give, apparently, one more normal mode of vibration to the linear molecules than to the corresponding non-linear. Two or more of the vibrations, however, are always degenerate; that is, two vibration forms have exactly the same frequency, so that the number of effective fundamentals is no greater. To illustrate, we may consider the diagrams of the vibration forms of a symmetrical linear triatomic molecule of the general formula XY_2 (CO_2, CS_2, etc.) (Figure 3). In the first, the two Y atoms vibrate in and out, the X atom remaining stationary. Since this type of molecule is symmetrical and possesses no permanent electric moment, and it retains this symmetry during the vibration, ν_1 will not be active in the infra-red. In ν_2, on the other hand, the two Y atoms move together against the X. Here the symmetry is destroyed and an electric moment results from the closer approach of the X to one Y than to the other. In ν_3 again there is a movement of charge relative to the center of gravity of the molecule, giving rise to an electric moment, so both ν_2 and ν_3 may appear in the absorption spectrum. It may be seen that the frequency ν_3 is independent of the direction in which the X atom moves, as long as it stays in a plane perpendicular to the line of centers of the Y atoms. This, then, is the doubly degenerate frequency, which completes the $3n-5$, or 4, normal modes of vibration.

In fact, the general orbit of the X atom in the ν_3 vibration is circular or elliptical in this perpendicular plane, giving rise to a small amount of angular momentum in connection with the vibration. The energy associated with this angular momentum is quantized independently of the vibrational energy, which results in a splitting of certain of the vibrational levels. Now, in order to describe our energy levels completely, we must introduce, in addition to the previously discussed quantum numbers V_1, V_2, V_3, a fourth, commonly denoted as l, to take care of the angular momentum contribution. In case V_3 is odd, l may take on all odd values up to and including V_3, and if V_3 is even, l takes on all even values up to and including V_3. Thus, if V_3 is 1, l may have only the single value 1, but if V_3 is 2, l may be either 0 or 2. This means that, instead of the single band expected as a result of the transition from the ground state to the level $V_3 = 2$, two bands may appear with a small separation between them. The separation is a function of l^2. A rotation of this molecule is very similar to the rotation of a diatomic molecule, the rotational energy being given by an equation of the same form, $W_R = (h^2/8\pi^2 I)(J(J+1))$, where I is the moment of inertia about the center of gravity of the (stationary) system. The selection rules for ν_1 and ν_2 are the same as those for a diatomic molecule, namely $\Delta J = \pm 1$, so that these two bands consist simply of a series of equally spaced lines with a missing line at the center. For ν_3, however, and, in fact, for any vibration in which the change in electric moment has a component parallel to the axis of rotation, the transition $\Delta J = 0$ is also permitted. This means that we may have transitions in which only the vibration quantum number changes, giving rise to a very strong line at the center of the band. The shapes of these bands are shown in Figure 4. In the diatomic or "doublet" type band, the part on the low wave-length side of the center is called the R branch and that on the long wave-length side the P branch. In the other type, the high maximum in the center is known as the Q branch and the others are named as above. This band is known as the Q branch type. The relatively much greater intensity of the Q branch compared with that of the others results from the fact that this line is due, not to a transition between a given pair of J levels, but to a sum of transitions involving all J levels.

The type of linear molecule discussed above has, as we have seen, no permanent electric moment and, hence, has no pure rotation spectrum. Examples are known, however, of asymmetric linear molecules, such as HCN and N_2O (N—N—O) which do possess an electric moment. In these cases, the rotation spectrum is of the particularly simple type found in the diatomic molecule, consisting of a series of equally spaced lines, the spacing being given by $\Delta\bar{\nu} = h/4\pi^2 Ic$.

Other examples of polyatomic linear molecules are cyanogen (C_2N_2), acetylene (C_2H_2), carbon suboxide (C_3O_2), and diacetylene (C_4H_2). For these molecules of more than three atoms, the vibration forms will, of course, be different from those shown above for the CO_2 type, but may be divided into the same two general classes, namely those in which the electric moment change is parallel to the line of centers, and which give rise to doublet type bands, and those in which the electric moment change is perpendicular to the line of centers, which give rise to Q branch bands.

HYDROGEN CYANIDE

As a specific example of the type of molecule considered in the previous section, we shall take HCN.* This is known to be a linear model, and to have the unsymmetrical structure H—C—N. The fact that this molecule is unsymmetrical will, of course, change the relative amplitudes of motion in the fundamental modes as pictured above, but the general shape remains the same. As we have seen, four quantum numbers are necessary to designate all the possible vibrational levels of this molecule, and these are V_1, V_2, V_3, corresponding to the three fundamentals, and l, which was discussed above. The most recent measurements on the near infra-red spectrum of this molecule are by Adel and Barker (*10*), and in the table below are shown the positions and assignments of the principal bands as given by them. The columns V_1, V_2, V_3, and l give the quantum numbers of the upper state. The lower state is in all cases the ground level.

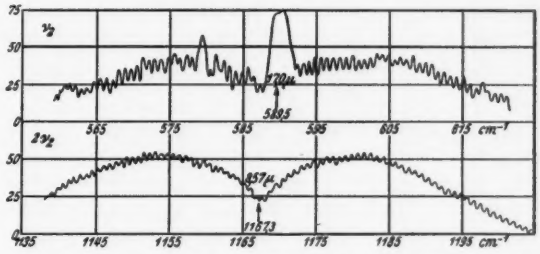

FIGURE 4.—Q BRANCH AND DOUBLET TYPE BANDS OF N_2O (PLYLER AND BARKER)

TABLE 1

FREQUENCIES AND QUANTUM NUMBER ASSIGNMENTS OF HCN BANDS

V_1	V_2	V_3	l	Frequency $cm.^{-1}$	V_1	V_2	V_3	l	Frequency $cm.^{-1}$
0	0	1	1	712.3	0	1	1	1	4005.6
0	0	2	0	1412.4	2	0	1	1	4993.9
1	0	0	0	2089.0	1	1	0	0	5395.0
0	0	3	1	2117.3	0	2	0	0	6523.5
1	0	1	1	2801.1	1	2	0	0	8591.0
0	0	4	0	2800.0	0	3	0	0	9645.0
0	0	4	2	2815.0	1	3	0	0	11674.5
0	1	0	0	3312.9	0	4	0	0	12635.8

All those bands in which the quantum number V_3 appears an odd number of times have Q branches, while

* Although CO_2 is usually given as the classical example of the linear triatomic molecule, this spectrum exhibits certain peculiarities as a result of an accidental degeneracy and so will not be discussed here. For a full treatment, the reader is referred to the papers of Fermi (*8*) and Adel and Dennison (*9*).

all others are of the doublet type. The fundamental ν_1 is theoretically active in the infra-red, but it has never been observed because of the heavy absorption in that region due to $3\nu_3$. This fundamental is, however, of the type that appears most strongly in the Raman effect, and, in fact, the value given above is taken from Raman measurements.

Adel and Barker found that though the frequencies of the higher harmonics and combinations were not well fitted by a simple expression in which a sum was made of each fundamental appearing, multiplied by its appropriate quantum number, the data could be very closely fitted by an equation of the form

$$\nu_v = X_1V_1 + X_2V_2 + X_3V_3 + X_{11}V_1^2 + X_{22}V_2^2 + X_{33}V_3^2 + X_{ll}l^2 + X_{12}V_1V_2 + X_{13}V_1V_3 + X_{23}V_2V_3$$

The values of the constants are as follows:

$X_1 = 2037.0$ cm.$^{-1}$	$X_{11} = 52.0$ cm.$^{-1}$	$X_{12} = -15.1$ cm.$^{-1}$
$X_2 = 3364.2$	$X_{22} = -51.3$	$X_{13} = -0.2$
$X_3 = 712.1$	$X_{33} = -2.9$	$X_{23} = -19.6$
	$X_{ll} = 3.1$	

It may be seen that X_1, X_2, and X_3 are rather close in value to their respective fundamental frequencies, while the others are, in general, of a smaller order of magnitude. These latter are known as the anharmonic constants of the molecule, and are a measure of the degree to which the system departs from the simple Hooke's law potential. The fundamental frequencies may be taken as 2089 cm.$^{-1}$, 3312.9 cm.$^{-1}$, and 712.3 cm.$^{-1}$. From these values a rough calculation of the principal force constants in the potential function may be made. If k_1 is the constant for the C—H bond, and k_2 for the C—N bond, they have approximately the values $k_1 = 5.8 \times 10^5$ dynes/cm. and $k_2 = 17.8 \times 10^5$ dynes/cm. These values are in fair agreement with those commonly accepted for these bonds.

Choi and Barker (*11*), from measurements on the line spacings in infra-red bands, found the moment of inertia of this molecule to be 18.68×10^{-40} g.-cm.^{2}, while Badger and Binder (*12*), who measured bands occurring in the photographic region of the infra-red, found 18.79×10^{-40}. There are, of course, two interatomic distances to calculate, but we have only the one piece of information at our disposal. However, the length of the C—H bond is known to be very nearly constant in all compounds in which it occurs, and its value is usually taken as 1.06 Å. It is a simple matter to calculate the moment of inertia of this body about its center of gravity, in terms of the three masses and the two distances. Assuming, then, the above value of C—H, and taking $I = 18.79 \times 10^{-40}$, we find that the C—N distance in this compound is 1.16 Å., which agrees well with the value found for this bond in other compounds.

The unsymmetrical HCN molecule possesses a permanent electric moment and should, therefore, exhibit a pure rotation spectrum. Apparently no measurements have been made on HCN in this region.

THE SYMMETRIC TOP

The next general class of molecules to be discussed is that known as the symmetric top rotator. The distinguishing characteristic of this type is that two of the moments of inertia are equal. In our notation, I_A, I_B, and I_C are the moments about the three principal axes of the molecule. (The principal axes are an orthogonal set, one of which is usually along the principal symmetry element of the molecule, or in some direction which has a special significance; thus, in the NH_3 molecule, one of the axes is through the N atom and perpendicular to the plane of the H atoms.) We shall use I_A to symbolize the two equal moments and I_C for the unique moment. A general rule is that only molecules containing a three-fold or higher symmetry axis may be symmetric tops.*

In a molecule possessing such a high symmetry, it is very likely that some of the frequencies will be degenerate. Not infrequently, then, our symmetric top molecule will exhibit fewer than the $3n$-6 fundamentals which it is permitted to have. It might be mentioned here that, on symmetry grounds alone, there may never be more than three fundamentals with the same frequency, and this three-fold degeneracy is permitted only in molecules with tetrahedral, or higher, symmetry.

We have here, of course, in the infra-red absorption spectrum a series of bands which are to be correlated with the various fundamentals in much the same way as in the previous case. Since the proper assignment depends to a considerable extent upon the rotational structure of the individual bands, we may pass at once to that subject and see what we may expect theoretically. The equation giving the rotational energy of a symmetrical top has been derived by quantum mechanical methods, and may be written down rather simply.

$$W_R = \frac{h^2}{8\pi^2 I_A} J(J+1) + \frac{h^2}{8\pi^2}\left(\frac{1}{I_C} - \frac{1}{I_A}\right) K^2 \quad |K| \leq J$$

Here the I's are as we have defined them above, and J and K are both quantum numbers. J may take on integral positive values, and K, integral positive or negative values. In this case, then, the energy is governed by the values of two quantum numbers, both of which may change simultaneously. Here again, the rotational selection rules depend upon the direction, relative to the principal axes, in which the electric moment is changing in the vibration associated with the rotational transition. The two cases are:

I. The change in electric moment is parallel to the axis of unique moment of inertia. Here the selection rules are $\Delta J = \pm 1, 0$ ($\Delta K = 0$) and we obtain the so-called parallel type band.

II. The change in electric moment is perpendicular to the axis of unique moment of inertia. The selection rules are $\Delta J = \pm 1, 0$ ($\Delta K = \pm 1$) and the band is called a perpendicular type.

Let us first consider the parallel type band. Since the second part of the above formula contributes noth-

* A special case of the symmetric top is the spherical top molecule, in which $I_A = I_C$. Examples of this type are CH_4 and CCl_4, the peculiarities of whose spectra are discussed by Johnston and Dennison (*13*).

ing to the structure, we have simply the familiar Q branch type band, with a constant line spacing determined by the two equal moments of inertia, I_A. This is then a band of very simple structure which should be readily analyzed and which leads to a value for I_A only.

The perpendicular type band is considerably more complex in structure, since changes in both quantum numbers enter. In case I_C is considerably smaller than I_A, which is true in a number of molecules such as CH_3Cl and the other methyl halides, then the energy spacing in the spectrum due to changes in K is much larger than that due to changes in J. We may then consider the whole band as made of a number of distinct sub-bands, each centered around a K transition, as shown in the diagram below (Figure 5). Here, for each change in K by ± 1, there is a strong line corresponding to the $\Delta J = 0$ transition, surrounded on each side by a number of equally spaced weaker lines corresponding to transitions between the various higher J levels. That is, the band as a whole is simply a composite built up of a number of diatomic-like bands. It is to be noted, though, that due to the restriction $|K| \leqslant J$ there are one or more lines missing on each side of the center line, depending on the magnitude of the particular K level involved. Whether I_C is less than I_A or not, this type of band will appear, under low resolution, to consist of a set of equally spaced maxima, resulting from the "Q branches" of the individual K transitions. This large spacing, which, as may be seen from the energy equations, is equal to $h/4\pi^2c \cdot \frac{h}{4\pi^2 c}(1/I_C - 1/I_A)$ cm.$^{-1}$, leads to a value for $1/I_C - 1/I_A$. If the band is re-examined with dispersion sufficient to resolve the fine structure due to J transitions, the spacing of which is $h/4\pi^2c \cdot \frac{h}{4\pi^2 c} I_A$ cm.$^{-1}$, the data are sufficient to determine uniquely both moments of inertia from the one band.

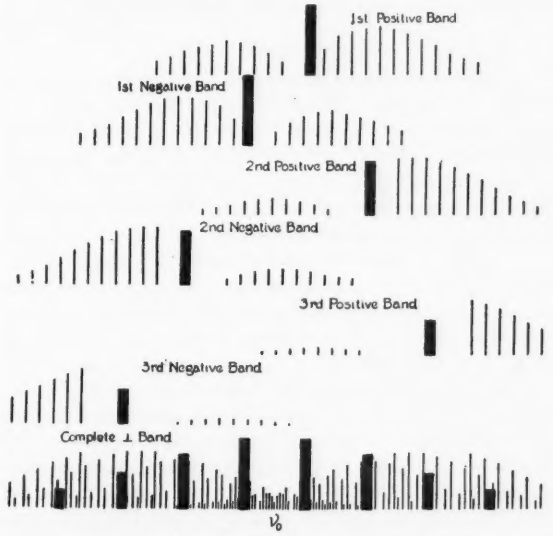

FIGURE 5.—DIAGRAM SHOWING THE COMPONENTS OF A PERPENDICULAR TYPE OF A SYMMETRIC TOP ROTATOR (DENNISON)

In the pure rotation spectrum, the above energy equation still holds. Since, due to the symmetry of the system, the permanent electric moment, if it exists, is parallel to the unique axis, the selection rules are $\Delta J = \pm 1$; $\Delta K = 0$. The pure rotation spectrum, then, of such molecules as NH_3 and the methyl halides consists of a series of equally spaced lines of separation $h/4\pi^2cI_A$ leading to a value for only one moment of inertia, I_A.

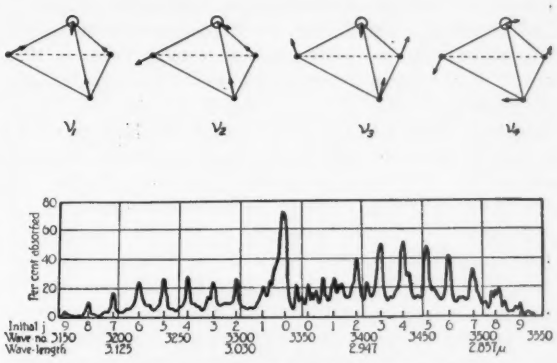

FIGURE 6.—THE UPPER DIAGRAM SHOWS THE NORMAL MODES OF THE PYRAMIDAL MOLECULE XY_3. THE LOWER SHOWS THE ABSORPTION AT THE ν_1 FUNDAMENTAL OF NH_3 ACCORDING TO STINCHCOMB AND BARKER

AMMONIA

The simplest molecule to discuss under this heading, and the one which has been most studied, both in the near and far infra-red, is that of NH_3. The form of this molecule is that of a regular pyramid with the N atom at the apex. Of the four independent vibration modes, ν_1 and ν_3 are of the parallel type and ν_2 and ν_4 perpendicular. The latter two are both doubly degenerate, thus accounting for the six modes allowed this molecule by theory. All four of these modes are active as fundamentals in the infra-red. According to the latest assignment by Howard (*14*), only three of these actually appear, but the frequency of the fourth may be estimated from a combination of this with one of the other fundamentals which does appear. In Figure 6 are given diagrams of the normal modes of NH_3, together with a curve showing absorption at the ν_1 fundamental. According to Howard, the frequencies of the four fundamentals of the ammonia molecule are as follows: $\nu_1 = 3335$ cm.$^{-1}$, $\nu_2 = 3450$ cm.$^{-1}$, $\nu_3 = 952$ cm.$^{-1}$, and $\nu_4 = 1631$ cm.$^{-1}$. He has calculated from these values, using a rather simple potential function, that the force constant governing the stretching of the N—H bond has the value 6.35×10^5 dynes/cm.

The rotational fine structure of the two parallel type fundamentals has been investigated by Barker (*15*) and by Stinchcomb and Barker (*16*). As we have seen, this type of band should consist of a series of equally spaced maxima, the spacing to be determined by the moment of inertia I_A. In the ν_1 fundamental, this spacing is found to be 19.67 cm.$^{-1}$, as a mean value over the whole band. In the ν_3 fundamental at 952 cm.$^{-1}$, each of the lines, as well as the Q branch, is found to be double, with a separation of about 33 cm.$^{-1}$. As a result of this doubling, the spacing can be measured less accurately, but none the less, a mean value of 19.5 cm.$^{-1}$ is obtained, in good agreement with the above. To anticipate a bit, this doubling in the 952 cm.$^{-1}$ fundamental results from the fact that the NH_3 pyramid has a rather small altitude compared with its other dimensions. The N atom is then able to jump through the H triangle from one side to the other without much difficulty. It is the interaction of this "inverting" frequency with the frequency of the fundamental that causes each of the lines to be double. In the ν_3 fundamental, as can be seen from the diagram, the H atoms are spreading apart as the N approaches their plane, thus making the jumping through rather easy, while in the ν_1, on the other hand, the opposite is the case. In ν_1 the repulsion between H and N plays a larger rôle, the jumping through is harder and occurs much less frequently. The interaction in this case produces such a small doubling as to be unresolvable in Barker's apparatus. Dennison and Hardy (*17*) have since resolved this splitting, and find it to be 1.6 cm.$^{-1}$.

When we come to the consideration of the perpendicular bands, more difficulties arise. The ν_4 fundamental at 1631 cm.$^{-1}$, as well as a combination band at 5084 cm.$^{-1}$, have been examined rather carefully and, though it is found that under low resolution the envelope consists of a series of maxima as was predicted by theory, this spacing is not the same in the various bands observed. This problem was troublesome for quite a time, but the difficulty has been recently resolved by Johnston and Dennison (*13*). Both of the perpendicular type fundamentals, as we have seen, are doubly degenerate vibrations. In such a case where, essentially, two vibrations are being carried out at right angles, the effect is to make each atom follow a circular or elliptical orbit. The interaction of this rotation with the rotation of the molecule as a whole introduces a Coriolis force which appreciably perturbs the rotation levels. This perturbation varies according to the particular band under consideration, and leads to the previously noted variability of rotational spacing. For the details, the reader is referred to the original paper. We will present here only the final results. Johnston and Dennison find that the ratio between I_C and I_A is about 1.65. The value of I_A can be obtained from the measurements of the parallel type bands in the near infra-red, but probably the pure rotation spectrum measurements are more accurate. The most recent work in this field is by Barnes (*18*, *19*) who found an average spacing of 19.88 cm.$^{-1}$. Since $\Delta\nu = h/4\pi^2 cI_A$, we can now calculate values for the two moments. These are

$$I_A = 2.79 \times 10^{-40} \text{ g.-cm.}^2$$
$$I_C = 4.60 \times 10^{-40} \text{ g.-cm.}^2$$

In terms of the masses and distances involved

$$I_A = \frac{3\,mM}{3m + M}\,a^2 + \frac{3m - M}{3m + M}\,\frac{I_C}{2}$$

where M is the mass of nitrogen, m that of hydrogen, and a is the N—H distance. From this we obtain the value of 1.02 Å. for the N—H distance. This is in good agreement with the value of 0.99 Å. which has been found in other molecules. Since $I_C = mb^2$ if b is the H—H distance, we may find a value, 1.66 Å., for b. Combining this value for b with that of a, we can calculate the height of the pyramid, which is 0.35 Å. By combining measurements on the pure rotation spectrum of NH_3 with those on its heavy hydrogen isomer, ND_3, Barnes found the height of the NH_3 pyramid to be 0.36 Å., so the agreement here is also satisfactory.

THE ASYMMETRIC TOP

By far the greater number of molecules known are of symmetry too low to belong even to the symmetric top class, and these all come under the general heading Asymmetric Top Rotators. Here all three moments of inertia are distinct in value, and most of the simplicity of structure noticed in the vibration-rotation bands of the previous classes vanishes. It may be noticed that in the symmetric top formula, the rotational energy did not depend upon the sign of the quantum number K. In the asymmetric top this two-fold degeneracy is removed and each level, except those for which $K = 0$, is split into two. In a molecule not far different from the symmetric top, that is, one in which two moments of inertia are nearly equal, this splitting may be small, and the band will retain most of the salient features of the parallel or perpendicular type symmetric top band. In the average molecule, however, such is not the case—the splitting is large and the lines seem to be distributed throughout the band without any particular rhyme or reason. The number of molecules whose rotational structure in the vibration-rotation bands has been completely and satisfactorily analyzed is very small, the principal ones being H_2O, H_2S, and HCHO. The reasons for this small degree of success, in spite of the large amount of time and energy expended on molecules of this type, are not far to seek. One reason lies in the experimental data. For most asymmetric top molecules, particularly if the moments of inertia are rather large, the spacings between many of the apparently randomly scattered lines are smaller than the resolving power of the instruments available for the investigation. Under these conditions, whole groups of lines may appear as a single hump in the spectrum, or, in extreme cases, whole regions of the band may give the impression of continuous absorption.

The other principal reason for this failure to interpret asymmetric top spectra is to be found in the com-

plexity of the theoretical equations. The quantum mechanical theory of the rotation of a body, all three of whose moments of inertia are different, has been worked out completely by Casimir (*20*), Wang (*21*), Kramers and Ittmann (*22*), Klein (*23*), Dennison (*5*), and others. It is, in this case, impossible to represent the energy of all rotational levels by a single equation as was done previously for the simpler cases. Instead, it is necessary to solve, for each value of the number J, a "secular" determinant of order J if J is odd, $J + 1$ if J is even. The rotational energy appears as a parameter in this determinant. The solution of this problem becomes quite difficult for high J values, and usually must be obtained by an approximation method for each individual molecule studied. For further information on this subject, the reader is referred to Dennison's paper for general theory, to those of Mecke and his collaborators (*24*, *25*, *26*) for the application to the H_2O molecule, and to that of Cross (*27*) for the application to H_2S.

FIGURE 7.—NORMAL MODES OF THE SYMMETRICAL NON-LINEAR TRIATOMIC MOLECULE XY_2

WATER VAPOR

The asymmetric top molecule about which the greatest amount of experimental information has accumulated is that of H_2O. This is partly because of the presence of H_2O in the atmosphere, causing water bands to appear as absorption regions in the solar spectrum. A total of seventeen bands are known and have been assigned as fundamentals, overtones, and combinations of the three fundamental modes allowed to this molecule. Fortunately, the moments of inertia of this molecule are small so that the lines are resolvable, and the rotational fine structure of most of these bands has been analyzed by Mecke and his collaborators.

The forms of the three fundamental modes are shown above in Figure 7. Dennison has shown that, for a molecule of this general type, if the change in electric moment during the vibration is parallel to the axis of least moment of inertia, the band may be expected to show a structure similar to the Q branch type of simpler molecules, while if the change is along the axis of medium moment, this structure does not appear. Since it is known that the bond angle in H_2O is in the vicinity of 100°, the axis of least moment of inertia is that perpendicular to the line bisecting the H—O—H angle. The axis of medium moment is along the bisector, while that of greatest moment is, of course, perpendicular to the plane of the molecule. This being the case, we may expect the fundamental ν_1 to possess a Q branch, while the other two will not. Furthermore, according to selection rules, overtones and combinations in which the fundamental ν_1 is contained an odd number of times will also exhibit a Q branch while all others will not. This gives us then a useful criterion for assigning the observed bands. The wave numbers of these band centers, together with their type and the assignment, is given in Table 2. Bonner (*28*) has shown

TABLE 2

QUANTUM NUMBER ASSIGNMENTS AND FREQUENCIES OF THE H_2O BANDS

Assignment			Type	Frequency	Assignment			Type	Frequency
V_1	V_2	V_3		cm.$^{-1}$	V_1	V_2	V_3		cm.$^{-1}$
0	0	1	D	1595.5	1	2	1	Q	12151.22
0	0	2	D	3152.0	3	0	1	Q	12565.01
0	1	0	D	(3600)	1	3	0	Q	13830.92
1	0	0	Q	3756.5	3	1	0	Q	14318.77
1	0	1	Q	5332.3	1	3	1	Q	15347.91
1	1	0	Q	7253.0	3	1	1	Q	15832.47
1	1	1	Q	8807.05	1	3	2	Q	16821.61
1	2	0	Q	10613.12	1	4	0	Q	16899.01
3	0	0	Q	11032.36	3	2	0	Q	17495.032

that all of these bands may be fitted very closely by an equation quadratic in the quantum numbers V_1, V_2, and V_3 of the form

$$\nu = X_1V_1 + X_2V_2 + X_3V_3 + X_{11}V_1^2 + X_{22}V_2^2 + X_{33}V_3^2 + X_{12}V_1V_2 + X_{13}V_1V_3 + X_{23}V_2V_3$$

in which the nine X's are constants to be determined from the observed spectrum. Bonner also calculated, from the vibrational data, the principal force constants of this molecule. That for stretching of the O—H bond has the value 8.233×10^5 dynes/cm., while the one regulating deformation of the H—O—H angle is 0.376×10^5 dynes/cm.

Mecke, as a result of his rotational analysis, was able to obtain extremely accurate values of the moments of inertia. From these he calculated the O—H distance in this molecule to be 0.956 Å. and the H—O—H angle to be 104° 36′.

THE SPECTRA OF LIQUIDS

When we pass, with a particular molecule, from the gas to the liquid, it is obvious that the molecule will continue to absorb, but the new regions are not necessarily the same as those observed in the gas. This is particularly true of highly polar molecules, such as water, where large intermolecular forces resulting from the close proximity of the individual molecules markedly affect the positions of the energy levels. Association and polymerization also change greatly the character of the absorption, causing bands to disappear, new bands to appear, and shifting the positions of others. In numerous organic liquids the frequency shifts in passing from the gas to the liquid, while existent, are not large, and no spurious effects are introduced. It has been shown that a study of the absorption spectra in the liquid phase can be most profitable in the investigation of these molecules. Already sufficient data have accumulated to permit the identification of bands due to the vibrations of a number of bonds. This study, although semiempirical, will undoubtedly be of great assistance in the determination and prediction of the structures of molecules of this kind.

THE SPECTRA OF CRYSTALS

Several types of crystals exist, and before discussing the infra-red spectra of crystals in general we must first describe these types very briefly. In a great many cases, the crystal structure, as shown by X-ray diffraction and other methods, is made up of ions, and is spoken of as an ionic lattice. The alkali halides, for example, are formed of two interlocked lattices, namely, those of the positively charged metal ions and of the negatively charged halogen ions. It may easily be shown that the vibration of these lattices with respect to each other will be optically active, and so give rise to infra-red absorptions. In more complicated ionic crystals, several neighboring atoms may unite to form an ion, such as, for example, the negative $CO_3^=$ group in the carbonates. The $CO_3^=$ group itself possesses several definite absorption frequencies in addition to the frequency accompanying the relative vibration of positive and negative ions. A second type of structure is found in crystals in which the building

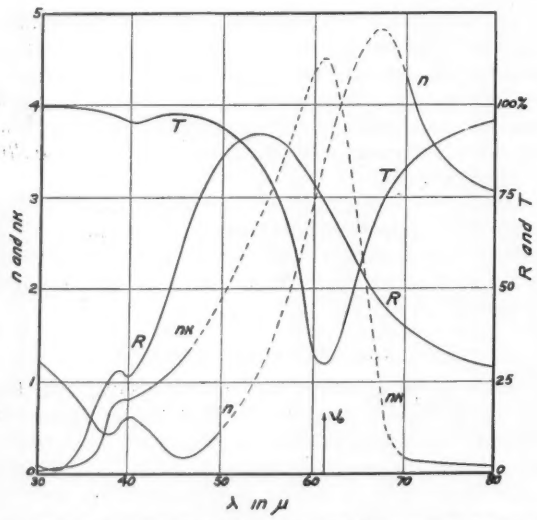

FIGURE 8.—DIAGRAM SHOWING THE REFRACTIVE INDEX n, THE ABSORPTION COEFFICIENT nK, THE REFLECTION POWER R, AND THE TRANSMISSION T FOR NaCl AS A FUNCTION OF WAVE-LENGTH

stones of the lattices are molecules, not ions. Many complicated organic compounds, as well as certain inorganic compounds, exist in the form of molecular crystals, and show strong infra-red absorptions. These bands, however, arise from vibrations which take place within the individual molecules, and not from lattice vibrations.

It might be mentioned at this point that also amorphous solids such as glass, fused quartz, etc., which are in reality supercooled liquids, possess infra-red absorption bands which are caused by the vibrations characteristic of the various groups of atoms present. In some cases, too, absorptions appear which are characteristic of the lattice of the corresponding crystal. These probably result from the presence of small recrystallized regions in the amorphous material.

In ionic crystals we may not speak of individual molecules, but must consider the entire crystal as one large polyatomic molecule. Assuming that the amplitudes of vibration are very small compared with the

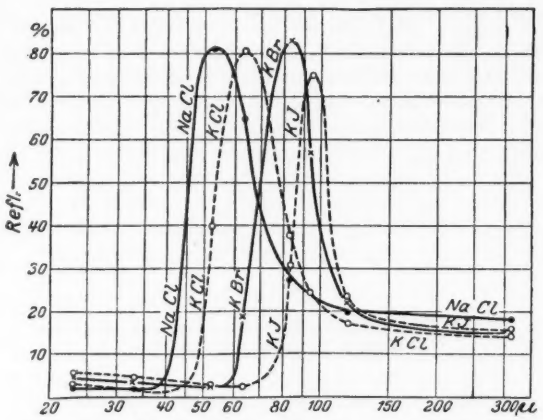

FIGURE 9.—RESTSTRAHLEN OF A FEW ALKALI HALIDES. HERE REFLECTIVITY IN PER CENT. IS PLOTTED AGAINST WAVE-LENGTH (LIEBISCH AND RUBENS)

distances between neighboring atoms and that Hooke's law forces exist, we may proceed to set up a suitable expression for the potential energy function, to determine the normal modes of vibration, and then to seek the proper selection rules. For a detailed discussion of this question, the reader is referred to the original paper of Brester (*29*). Rotations, in general, do not occur, and so the problem is one of vibrations only. Without discussing these methods further, we shall proceed to the experimental topics.

CHARACTERISTIC FREQUENCY

In the vicinity of a characteristic frequency, ν_0, the optical constants assume extreme values. Since the reflection power

$$R = \frac{(n-1)^2 + n^2K^2}{(n+1)^2 + n^2K^2}$$

and the transmission

$$T = \frac{1}{1 + 4nK(\pi d/\lambda) + ((2nK)^2 + (n^2 - K^2 - 1)^2)(\pi d/\lambda)^2 + \ldots}$$

where n is the refractive index, K the extinction coefficient, and d the thickness of the layer, we should expect R to reach a maximum and T to reach a minimum close to ν_0. Careful examination of these two equations shows that the transmission minimum lies somewhat closer to ν_0 than does the reflection maximum. In fact, it has recently been shown (*30*) that if a suffi-

ciently thin layer of the crystal be used, $T_{min.} = \nu_0$. Thus, although this is the only method of obtaining absolutely accurate values of ν_0, a very good approximation may be found by locating either $T_{min.}$ for a thicker plate, or $R_{max.}$. Figure 8 illustrates clearly the facts just discussed. In locating $R_{max.}$, one uses, wherever possible, a highly polished plate of a single crystal of the material being studied, and interchanges it at every wave-length with a silvered mirror. In those cases where large pieces of crystals are not available, one must resort to a reflection plate, which is prepared by pressing some very finely powdered crystals against a steel mirror. In general, the frequency of $R_{max.} > T_{min.} > \nu_0$.

RESTSTRAHLEN

As was indicated in Part I, one method of obtaining monochromatic radiation in the far infra-red is by the use of so-called "reststrahlen" or "residual rays," obtained when continuous radiation is allowed to reflect

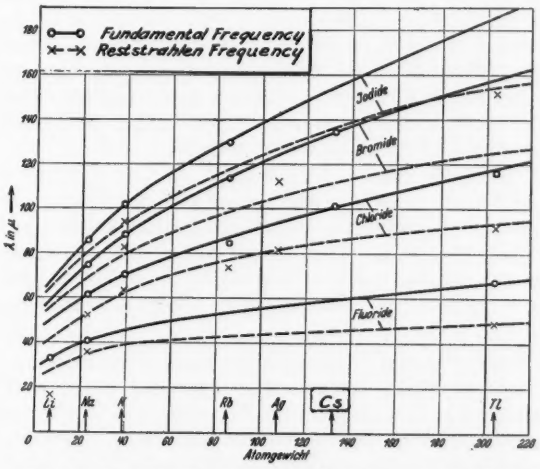

FIGURE 10.—THE FUNDAMENTAL FREQUENCIES AND REST-STRAHLEN FREQUENCIES OF THE ALKALI-METAL AND MONO-VALENT THALLIUM HALIDES PLOTTED AGAINST ATOMIC WEIGHT OF THE METAL ION (BARNES)

successively from several crystal plates. Such reststrahlen are shown in Figure 9, which is taken from a paper by Liebisch and Rubens (*31*). The principle of the method may be made clear very easily. The reflection power in the region of anomalous dispersion is given by

$$R = (n - 1)^2 + n^2K^2/(n + 1)^2 + n^2K^2,$$

and that in the region of normal dispersion by $r = (n - 1)^2/(n + 1)^2$, since there K becomes vanishingly small. If I represents the ratio of the original intensities in these two regions, we have after n reflections $I_n = I(R/r)^n$. If now we assume the reasonable values $I = 1$, $R = 0.9$, and $r = 0.45$, we see at once that $I_n = 2$ for $n = 1$, and $I_n = 16$ for $n = 4$. Thus, after four reflections only a narrow band of reflected energy remains.

The bands of monochromatic radiation thus obtained are very useful for the purpose discussed in Part I, but it must be emphasized that the frequency $\nu_{rest.} \neq \nu_0$. Figure 10 shows the frequencies $\nu_{rest.}$ and ν_0 for the alkali halide crystals (*32*).

INNER AND OUTER VIBRATIONS

In ionic crystals, the vibrations of the positive lattice relative to the negative lattice are referred to as "outer vibrations." Those which take place

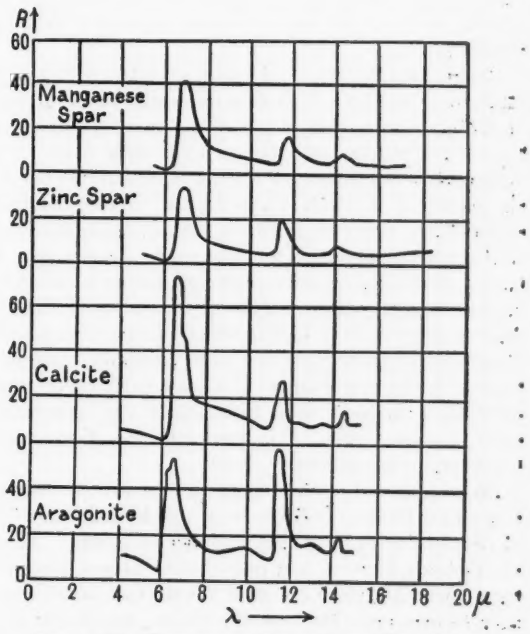

FIGURE 11.—REFLECTION SPECTRA OF A FEW NATURALLY OCCURRING CARBONATES, SHOWING THE MAXIMA CHARACTERISTICS OF THE CARBONATE ION

within an ionic group are known as "inner vibrations." Thus, NaCl crystals should possess only an outer vibration, while more complicated crystals such as $CaCO_3$, $CuSO_4$, etc., should possess both outer and inner vibrations. The latter, which characterize the $CO_3^=$ and $SO_4^=$ groups, persist even when the crystals are dissolved, while the former, of course, disappear. Outer vibrations generally occur in the far infra-red, while the inner vibrations, due to the higher energies involved, are found in the near infra-red. As is to be expected, the near infra-red spectra of all carbonates are strikingly similar. This is also true for the silicates, nitrates, chromates, iodates, sulfates, selenates, etc. (See Figure 11.)

QUALITATIVE RESULTS OF INFRA-RED SPECTRA

Before concluding this section on the interpretation of infra-red spectra, it might be well to give a few of the general qualitative and semiquantitative rules which have accrued from the comparison of results on many molecules.

One of the most important and useful of these rules is that of the constancy of interatomic distances. The distance between any pair of bonded atoms, connected always by the same type of bond, is found to be very nearly constant in whatever molecule it occurs. This has been applied to the covalent bonds in molecules both in the gaseous state and in the solid, for those cases for which accurate crystal structure data exist. Data also exist for ionic bonds, but since this is principally applicable to non-molecular structures in the crystal, we shall not concern ourselves with it here particularly.

As an example, the C—H distance is found to be very close to 1.06 Å., whether it is measured in C_6H_6, C_2H_2, or CH_4. This rule is of great use in determining molecular structures when the experimental data are insufficient to determine all the constants uniquely, as in the example of HCN given in the section on linear molecules. The rule must, of course, be applied with caution, and distinction must be made, for example, between the single, double, and triple bonds between two carbon atoms. Also, in case of resonance of the type discussed by Pauling (*33*) between two or more possible electronic structures for the same molecule, care must be used in its application. In the treatment of simple molecules, as well as in postulating the structure of more complex ones, this principle has been found, however, to be extremely handy.

So widespread is this constancy of interatomic distance that Pauling (*33*) has been able to draw up a table of covalent radii for a large number of atoms. To find the distance between any pair of these atoms, connected by a specific type of covalent bond, it is simply necessary to look up in the table the single-, double-, or triple-bond radius for each atom involved, and add the two values.

The same argument applies, but to a lesser extent, to the angles formed between two or more bonds to the same atom. The angle between the two bonds to oxygen in the case of H_2O, as well as in some of the organic ethers and other compounds, is found to lie usually between 105° and 115°. The forces controlling bond angles are, however, far weaker than those controlling distances, and the angle is much more susceptible to the effect of neighboring atoms or groups.

In addition to the above-mentioned constancy of bond distances and valence angles, there seems to be a considerable correlation in the frequencies of absorption bands in molecules containing specific groups. This constancy of group frequency appears not only in the spectra of gases, but also of numerous organic liquids. For example, nearly all molecules containing the C—H bond show a band at about 3.3μ, while if the CH_2 group is present there is, in addition to this band, another at about 6μ. The first is due to vibration of the H atom against the rest of the molecule, while the second results from the bending of the H—C—H angle. Characteristic bands are also found for molecules containing such bonds as C≡N, C═O, C═C, O—H, N—H, etc. This means simply that in most molecules in which these bonds occur, at least one of the fundamental modes is essentially a stretching of this bond. The effect of added weight and of perturbations resulting from the additional atoms hooked on may shift the position of the frequency appreciably, but usually not enough to make it unrecognizable.

One application of this principle of the constancy of bond frequencies is in the assignment of vibration frequencies to normal modes for a particular molecule. If some band can be recognized as due to the vibration of a particular bond, it can usually be safely assigned to a mode in which the principal motion is a stretching of that bond.

Another application is in the qualitative analysis of complex organic compounds (*34*). By running the absorption spectrum in the infra-red and sorting out the bands obtained, it may be ascertained whether or not the compound contains O—H groups, C—C bonds, N—H bonds, etc. The correlation of this information with the results of a chemical analysis may lead to a considerably better knowledge of the structure of the compound.

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A DEVICE FOR PRODUCING FLAME SPECTRA

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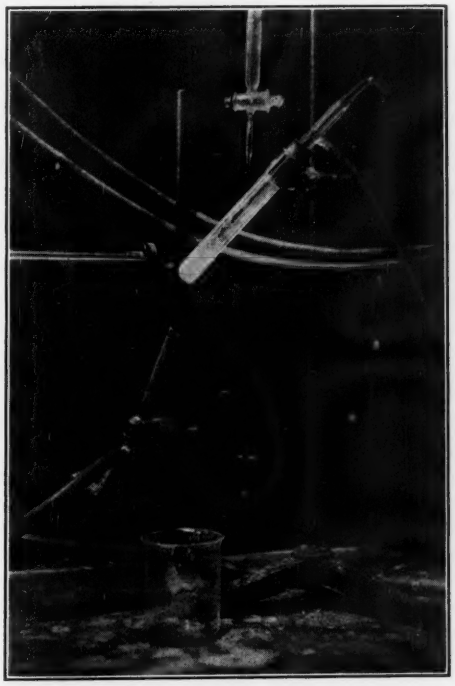
SINCE the test-tube method for flame testing produced several new flame tests for the common and rarer elements, it was of much interest to find what observations could be made by this method by using a spectroscope. For the work done on the common elements, and similar work on the rarer elements by this method, reference may be made to two papers of the author.[1,2]



The figure gives a close-up of the arrangement used for producing a spectrum by this method. The one end of the spectroscope may be observed to the extreme left. The Bunsen burner is placed at an angle so that any excess liquid will not disturb the flame. A two- to three-inch flame is used and a micro-buret is used to supply the liquid. The buret contains the solution to be analyzed and the stopcock adjusted so that a drop is liberated just as the preceding drop is dried upon the test-tube, thereby producing a continuous flame. After the arrangement is placed in working condition, only one individual is needed to do the spectrum work which is a great advantage in many respects, when compared with the use of the platinum-wire method in spectrum analysis, in qualitative analysis, and spectrum experiments in the elementary physics course.

A Hilger wave-length spectroscope was used in this work. The elements that produced flames by this method and did not produce any visible spectrum lines were tin, antimony, selenium, germanium, titanium, tellurium, nickel, aluminum, and bismuth. Strontium produced all of its ordinary lines, as did barium, calcium, sodium, potassium, lithium, thallium, indium, caesium, and rubidium. Lead, manganese, and copper produced rather broad bands; however, these are the only three heavy metals that produced spectra by this method, thereby making spectrum readings much easier for mixtures.

[1] CLARK, A. R., "The test-tube method for flame testing," J. CHEM. EDUC., **12**, 242–3 (1935).
[2] CLARK, A. R., "Test-tube flame test applied to the rarer elements," *ibid.*, **13**, 383–4 (1936).

It is the successful, or even the unsuccessful, pursuit of truth which gives happiness to each generation of scientific men, and not the value of the truth itself—the energy, the doing, not the thing done. If a time could arrive when all was known, when there could not be a new investigation or experiment, our keenest pleasure would be at an end. We may therefore feel happy in the thought of how much is still unknown.—A. G. VERNON HARCOURT

CONSTRUCTING *and* VALIDATING EXAMINATIONS*

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CONSTRUCTING and validating examinations involves a number of major problems. If we are to improve examinations, we must approach these problems with the attitude of the experimenter and study promising procedures for attacking them.

The most important problem is that of validity. Does the test give us evidence about that with which we are concerned? Does the test give evidence that the students are developing in the direction of the objectives of general chemistry teaching? Obviously, for most purposes, a single test will not give us valid evidence of all the important changes in the development of chemistry students. The break from the old type essay test to the new type test has too generally been accompanied by an increased emphasis on testing for a knowledge of subject matter content. This is unfortunate. Knowledge of subject matter is only one of the important objectives of college general chemistry. A test of information gives only one aspect of the picture of a student's development.

Teachers of general chemistry are concerned with a variety of objectives. Dr. O. M. Smith's[1] study of the objectives of general chemistry shows that general chemistry courses are designed to result in a number of important outcomes in students. The purposes are not limited to a knowledge of information. Although the relative importance of the objectives is not the same in every institution, there are several objectives which are generally thought to be fundamental. Some teachers regard the use of scientific method by students as the primary thing they are attempting to encourage; others will place factual knowledge first. Nevertheless, all agree that both are important objectives of general chemistry courses. As tests are developed for each objective, the examination program becomes more flexible. Each test can be evaluated according to the relative importance of the objectives of the individual teacher or the institution in which they are used. Furthermore, tests of some objectives may be omitted or included to fit the needs of particular institutions or classes.

With the statements of objectives at hand, it is necessary to make clear the meaning of each objective. What kind of behavior on the part of general chemistry students constitutes evidence that they are reaching each important objective? Specifically, what kind of evidence shows that students are acquiring a fund of chemical information; what evidence shows that they are learning to use chemical facts and principles in solving problems new to them; what evidence shows that they are learning to interpret experimental data; what evidence shows that they are developing the ability to plan experiments for testing promising hypotheses; what evidence shows that students are skillful in the use of laboratory technics; what evidence shows that they have an interest in chemical phenomena? Each objective, in turn, must be clarified in terms of the evidence and the kind of student behavior which expresses the objective. Evidence that a student has acquired a fund of chemical information has often been described as that obtained when the student is asked to state certain information. For example, he may be asked to state the characteristic properties of mixtures. Evidence of his knowledge may be found in his answer to the question. To obtain a reliable estimate of the degree to which a student has acquired information, studies have shown that it is necessary to present a large sample of questions. Under ordinary conditions it is not feasible to present students with a sufficiently large number of questions and have them answer the questions in their own words, either orally or in writing. This is an important practical problem in obtaining a satisfactory estimate of a student's progress in the direction of the objective. It is the problem of developing practicable examinations without sacrificing the primary characteristic of a test—its validity. Without practicable examinations, teachers tend to use easily constructed, easily scored, or short examinations, with little regard to whether or not the examinations give valid and reliable evidence of each of the important objectives.

A promising way out of this difficulty appears to be one of getting indirect evidence in a practicable manner, but which will give a satisfactory index of the direct evi-

* Contribution to the Symposium on Tests and Examinations, Kansas City Program, conducted by the Division of Chemical Education at the ninety-first meeting of the A. C. S., Kansas City, Missouri, April 14, 1936.

[1] SMITH, O. M. "Accepted objectives in the teaching of general college chemistry," J. CHEM. EDUC., **12**, 180–3 (1935).

dence, and thus retain validity. For example, a list of characteristic properties of mixtures and a list of students' misconceptions about mixtures may be prepared and presented to the students. They are asked to check only the statements of the true characteristic properties of mixtures. This appeared to be a promising practicable method of getting indirect evidence of a student's knowledge of the properties of mixtures. To check this hypothesis two tests were prepared. The first test consisted of ten questions, to which the students were asked to state their answers in their own words. The second test consisted of the same ten questions, but with provision for the student to check the appropriate statements which answered each question. Both tests were given to the same students. After the students had completed the first test, the papers were collected and the students were given the second test. The tests were graded, and the two grades of the same student compared in relation to the grades of all the students. This comparison revealed that a student who made a high grade on the first test made a high grade on the second test, and that a student who made a low grade on the first test made a low grade on the second test. In other words, the relationship between the two sets of grades on the two tests, containing ten questions each, was high (0.85). Since the second test can be more quickly administered and graded it may be used as a fairly valid index of students' knowledge of information.

The procedure of checking promising methods of collecting indirect evidence with direct evidence is not new. It has been used by the physicists in checking indirect evidence of temperature with direct evidence. Whenever it has been impractical to obtain direct evidence, valid indirect evidence has been very useful. The physician compares the color of the blood of a patient with a color chart in estimating the number of red blood-cells and the per cent. of hemoglobin in the blood. Several competent persons independently count the number of red cells in each of several samples of the blood only in exceptional cases when he wants direct evidence.

The application of facts and principles of chemistry[2] is another important objective of general chemistry. What does this objective mean? What can be expected of students as evidence that they are able to apply facts and principles of chemistry? The evidence which many science teachers accept is that obtained when students predict the probable outcome of a problem new to them and explain their predictions, using the facts and principles of the science. Students are expected to formulate their own predictions and explanations and state them in their own words. This is an indication of their ability to apply facts and principles in solving new problems. The problems should be new to the students so that they cannot depend upon their memory of particular solutions to particular problems. In order to collect this kind of evidence students must be given opportunities to demonstrate their ability to use pertinent facts and principles in solving new problems. This type of question is commonly found in teachers' essay examinations. A sufficiently large sample of these questions is time-consuming for students to answer and requires careful reading and grading by several competent persons. This is impractical with large groups of students. In considering possible procedures for obtaining indirect evidence which could be used as a valid index of students' ability to apply facts and principles, a promising procedure was suggested. This procedure consisted of presenting students with a new problem situation, a list of predictions and a list of statements including facts and principles and misconceptions which can be used to explain the predictions. For each prediction which a student checks, he can find supporting statements in the second list. In other words, the procedure should give the student an opportunity to check the things he has in mind, rather than write them in his own words—thus economizing the time devoted to satisfactory examinations. When the statements the student checks are assembled, they form a paragraph stating the prediction and an explanation of the prediction.

This procedure was considered a promising hypothesis which should be tested. Are conclusions about the students' ability to apply facts and principles drawn from this indirect evidence the same as conclusions drawn from the direct evidence when students formulate their answers in their own words? Do students who make a high grade on the direct-evidence test also make a high grade on the indirect-evidence test? Do students who make a low grade on the first type also make a low grade on the second? Two tests were prepared to determine the answers to these questions. The first test, containing ten problem situations, was administered to students who wrote their predictions and explanations in their own words. Immediately after completing the first test the students were given the second test containing the same ten problem situations and asked to check the statements which indicate the predictions and explanations. The direct evidence was carefully graded by five individuals. The correlation between the grades on the direct evidence and the grades on the indirect evidence was 0.82 for the ten questions. When more than ten questions are used the relationship is higher. Such indirect evidence may be used as a valid index of the direct evidence.

One problem in preparing questions for the short-cut test is that of formulating predictions and explanations which students make. Some of these should be correct and others should be misconceptions which students have. One can assemble a list of students' misconceptions by giving essay tests and analyzing the students' answers.

Another objective commonly stated for courses in general chemistry is an understanding of the technical terminology. The attainment of this outcome can be determined only when the objective is defined in terms of the behavior desired. The kinds of behavior which

[2] HENDRICKS, B. CLIFFORD, R. W. TYLER, AND F. P. FRUTCHEY, "Testing the ability to apply chemical principles," J. CHEM. EDUC., 11 (1934).

are called "understanding of technical terms" are somewhat varied. Students may be expected to define or describe certain terms in their own words. In such cases the direct test is to present the terms and ask the students to define each term in his own words. The major problem in evaluating the students' behavior on this type of test is to determine what are acceptable definitions or descriptions of the terms. For some terms very precise and accurate definitions may properly be expected; for other terms more general descriptions may be adequate; in some cases only the general implications of the term may need to be discussed. Promising indirect evidence which is feasible to obtain is secured by the use of the master list test. A numbered list of technical terms and a corresponding list of definitions or descriptions are presented to students who are expected to read each definition or description, decide what term it defines or describes and place the number of the term after the definition or description. The terms in the list may be alphabetized to facilitate finding the term which answers the description. The provision of more words in the list than there are definitions or descriptions helps to eliminate successful guessing in answering the questions. This type of test is useful in getting fine discrimination in terms. Two or more words closely related in meaning but distinct in some important aspect may be included in the list. Of course, the choice of such terms depends on the degree to which general chemistry students are expected to discriminate between terms.

This type of test was compared with the test in which students define or describe the terms in their own words. Students were given thirty terms and asked to define or describe them, that is, to state what these terms meant. Immediately after the students had completed the test the master-list test was given. When the grades of the students on the two tests were compared, it was clear that a student who made a high grade on the direct test made a high grade on the master-list test. A student who made a low grade on the direct test made a low grade on the master-list test. The coefficient of correlation was 0.81. The relationship is still higher when more terms are included in the tests.

Students are often expected to understand technical terms as they appear in reading. As students read chemical literature they may be expected to show that they understand the chemical terms by defining or describing these terms. At present we are experimenting with a test of this sort and checking the master-list test with it. As yet, no report can be given because the work is not completed.

A fourth objective of many general chemistry courses is the ability to interpret experimental data. Several kinds of indirect evidence of students' ability to interpret experimental data were considered. Each of these was checked in turn with the direct evidence in a search for indirect evidence which would give a valid index of the direct evidence. The results[3] of this research were reported at the New York meeting of the American Chemical Society.

One aspect of the ability to interpret experimental data is the recognition of the limitations of the data and of the conclusions which can be drawn from the data. That is to say, students may be expected to recognize interpretations which are entirely supported by the data, interpretations which are contradicted by the data, and interpretations which go beyond the data. The latter may be true or false; the data may give insufficient evidence to support these interpretations or they may be considered as promising hypotheses or good predictions. A second aspect of interpreting experimental data is in judging whether the interpretations which go beyond the data are probably true or probably false. Students may be expected to use other information in deciding upon the probable truth or falsity of these interpretations.

A fifth objective which many science teachers favor is the ability to plan experiments for testing hypotheses. As yet, we have not prepared examinations for this objective in chemistry though some work[4] has been done in botany and zoölogy. A student in zoölogy, for example, when asked whether temperature of the external atmosphere affects the rate of heart beat in the frog, should be able to describe the evidence which will answer this question and how this evidence can be collected; that is, he should be able to formulate the plans for an experiment which will show whether or not the temperature of the external atmosphere affects the rate of heart beat in the frog. Test situations for this behavior are hypotheses which have not been tested or with which elementary students would not be familiar. The student would be asked to describe an experiment, stating the evidence needed and procedures for collecting the evidence, which could be used to determine the truth or falsity of the hypothesis.

In experimenting with more practical tests for ability to plan experiments for testing hypotheses several kinds of indirect evidence have been considered and compared with the direct evidence. One test consisted of situations, each one containing a description of five possible experiments for testing the hypothesis given. The student was asked to indicate the experiment which he thought best for testing the hypothesis and also to indicate the experiment which he thought poorest. When the grades of students who took this test were compared with the grades of the same students who had taken the direct test, the correlation was only 0.63.

A second kind of indirect evidence was then considered. In this test descriptions of five possible experiments followed each hypothesis. The situations were the same as in the first indirect test, but the behavior of the student was different. He was asked to grade the experiments in order from 1 to 5 according to their suitability for testing the hypothesis. When the grades of

[3] FRUTCHEY, F. P., R. W. TYLER, AND B. CLIFFORD HENDRICKS, "Measuring the ability to interpret experimental data," J. CHEM. EDUC., **13**, 62–4 (1936).

[4] TYLER, R. W., "Ability to use scientific method," *Constructing Achievement Tests*, pp. 24–32 (1934). Reprints from the *Educational Research Bulletin*, Ohio State University.

students who took this test were compared with their grades on the direct test, the correlation was 0.79. This second indirect test gave closer results to the direct test than the first indirect test. We are still searching for indirect evidence which will be even more valid as an index of the direct evidence.

This brief description of methods of developing examinations shows the experimental approach. Some of the objectives of general chemistry were chosen for illustration. The problem of developing procedures for collecting evidence of achievement in the objectives of general chemistry involves two essential steps; first, a clear formulation of the kind of evidence which indicates achievement in each objective and second, devising procedures by which the evidence may be obtained. The direct evidence is time-consuming to collect and to evaluate, especially when teachers have large groups of students. Therefore, there is need for more practical procedures by which indirect evidence may be collected. The indirect evidence should give a valid index of the direct evidence. Practical tests should be checked periodically with the direct tests to determine whether the high relationship continues to hold year after year. Improving examinations is a coöperative enterprise. This coöperation means that teachers of chemistry and test technicians working together may make much progress in constructing examinations to fit the objectives of general chemistry.

BAKELITE TYPE PLASTICS—A DEMONSTRATION

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A RECENT article[1] by H. Lindner showed how a Bakelite-type plastic could be prepared in the school laboratory. Using the directions given, the present author found that although a suitable product was obtained, the procedure took too much time and was inconvenient for classroom demonstration. After many trials it was found that the following modification will allow the demonstrator to make a Bakelite-type plastic in one classroom period of about forty-five minutes, followed by subsequent baking.

Twenty-five grams of phenol and 50 cc. of 35 per cent. formaldehyde are heated with 3 cc. of 30–40 per cent. sodium hydroxide solution in a reflux condenser using a flash of about 40 cc. capacity. As the heating proceeds, the mixture changes to a red color and becomes more viscous. When approximately three-quarters of an hour has elapsed the contents of the flask will have assumed the consistency of molasses, and the bubbles which rise through the mass will encounter noticeable difficulty in escaping from the surface. This is the signal for removing the flame and immediately pouring the viscous product into a two-ounce wide-mouthed bottle until the latter is about three-quarters full. The substance at this time changes to a white material resembling dough. It is now ready for baking. The flask in which the mixture was heated should be cleaned as soon as possible with a strong caustic soda solution. If allowed to stand, the hardened product is difficult to remove.

The baking operation may be performed in a home-made oven constructed from a cylindrical can in which laboratory chemicals are shipped. The can should be about fifteen inches tall and six or seven inches in diameter. The cover is discarded and then the can is inverted over an ordinary electric light bulb screwed to a base and resting on the laboratory table. A hole is cut in what is now the top so that a thermometer may be admitted. The product in the wide-mouthed bottle is supported on a tripod and wire gauze over the bulb in the can. The legs of the tripod may be cut off somewhat if the latter occupies too much space in the oven. A few small holes about a quarter of an inch in diameter are bored around the top and bottom of the can to allow for air expansion.

The baking should be begun at a temperature of not more than 50°C. and after about two hours it should be increased to about 75°C. The author found that a fifteen-watt bulb would maintain a temperature in the neighborhood of 50°C. and a twenty-five-watt bulb was good for 75°C. The purpose of the baking is to dry the product, and too rapid heating would crack the plastic. A total of four hours of heating is usually sufficient but a better plan is to leave the material in the oven overnight at the lower temperature. Shrinkage takes place, and the bottle must be broken to remove the substance which now has a red color and is somewhat brittle but resembles the commercial products in appearance.

When a two-ounce wide-mouthed bottle is used for the mold, as suggested above, the shape of the product suggests an umbrella handle. Other molds, such as an ordinary test-tube, may be used. A very satisfying result is obtained by using one cover of a Petri dish.

[1] LINDNER, *Z. physik. chem. Unterricht*, **48**, 251 (Sept.-Oct., 1935).

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APPARATUS, DEMONSTRATIONS, AND LABORATORY PRACTICE

The light-bringer. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **127**, 2–3 (Aug., 1937).—Phosphorus gets its name from the fact that it glows in the dark. This luminosity filled its discoverers with wonder. As a curiosity it was exhibited at the courts of princes. Its preparation from urine was a secret kept religiously or sold for profit until its discovery in bones. Today phosphorus is made in the electric furnace from phosphate rock, but the product is dangerous to handle. The yellow variety of phosphorus was used formerly in the composition of "rat biscuits." It was also used in incendiary bombs for military purposes. Another allotropic form, which is red, non-volatile, and non-poisonous is used in safety matches and tracer bullets, as well as in fireworks. Dr. Percy Bridgman of Harvard has subjected yellow phosphorus to tremendous pressure, transforming it into a third variety which is black. This form loses its light-giving power and is a fairly good conductor of electricity and heat and does not ignite spontaneously. Even phosphorus compounds exhibit the light-bringing qualities. Calcium phosphide is the material contained in the red canisters attached to life belts which one sees fastened to the rails of passenger liners and other large ships. When the life belt is thrown into the ocean, the calcium phosphide produces hydrogen phosphide with the water which burns with a brilliantly luminous flame, helping the man overboard to find his way in the darkness. Trisodium phosphate is widely used as a scouring agent, thus bringing light into the home. It is the phosphates in the fertilizer which bring brilliance to the flower and the "light of satisfaction to the face of the gardener."

G. O.

Production of mirrors by evaporation of metals in a vacuum. A. B. FOCKE. *Rept. New Eng. Assoc. Chem. Teachers*, **38**, 149–50 (May, 1937).—During the past few years interest in the production of mirrors by the evaporation of metals in a vacuum has become very widespread. A simple apparatus to form such mirrors consists of a chamber formed by a steel base eighteen inches in diameter and one inch thick on which a twelve-inch bell jar rests. The chamber is evacuated by an Apiezon oil diffusion pump backed by a Megavac pump. The current leads for heating the filament are brought through the steel base by means of spark plugs. It is necessary to obtain a vacuum of about +10 to −3 or +10 to −4 mm. of mercury. This is about the pressure at which it becomes no longer possible to pass an electrical discharge through the remaining gas. In most cases the filament consists of a conical spiral of 15 ml. tungsten wire which acts as a container for the metal as well as a heating element. If the coils are fairly close together surface tension will prevent the molten metal from falling through. In the case of aluminum a small piece of $^1/_{16}$-inch aluminum wire is hooked over several turns of the tungsten wire. It is necessary to have the glass that is to be coated chemically cleaned and in addition to the chemical cleaning it is helpful to bombard the glass with a discharge from a high voltage source after it has been placed in the vacuum chamber. Mirrors of this sort have been made with Al, Ag, Au, Cu, Sn, and many other metals.

W. O. B.

Chemical durability of glass. V. DIMBLEBY. *Sch. Sci. Rev.*, **18**, 476–89 (June, 1937).—Since commercial glasses offer high resistance to attack by atmospheric and common chemical reagents, some means must be employed in the testing of glasses, to accelerate the action of the attacking agent. Apart from prolonging the time of test within reason, the attack upon glass may be accelerated by increasing the temperature, and increasing the surface area of glass exposed. The most important methods of test are as follows: (1) The dimming test—the glass is weathered by exposure to moist, pure air for definite periods at a carefully controlled temperature, and the surface examined microscopically. This test is used mainly for optical glasses. (2) Mylius weathering test—a freshly fractured glass surface is exposed to the action of moist air at 18°C. for seven days. The surface is then dipped into an ether solution of iodeosin for a minute, when the liberated alkali precipitates the ether-insoluble salt of the dye. This is dissolved in a definite amount of water and the tint compared against standards of known strength. (3) Extraction tests on vessels, etc.—neutral distilled water is allowed to stand at a definite temperature in contact with a cleaned surface for a definite period of time. The extent of attack is measured by the loss in weight of the glass specimen, or by the weight of the residue obtained by evaporating the solution to dryness, or by the alkalinity of the solution as obtained by titration, or by complete analysis of the solution. (4) Conductivity test—pure water is placed in the vessel to be tested and the increase in electrical conductivity is measured as time passes. (5) Autoclave test—this test is similar to (3), except that the glass is exposed to the action of water and steam in an autoclave. (6) Powder test—the glass is powdered to a definite size and submitted to the action of boiling water for a definite period. The analysis is similar to (3).

Chemical-resistant glass is usually more complex in composition than ordinary window or bottle glass, and generally contains appreciable proportions of aluminum and boric oxides, with a high silica content.

S. W.

Pressure cooking contributes increased cottonseed processing profits. R. B. TAYLOR. *Chem. & Met. Eng.*, **44**, 478–81 (Sept., 1937).—Increased yield of superior quality oil, with materially less cooking time, has been demonstrated as a new avenue to increased profits at the University of Tennessee's Engineering Experiment Station. It has been shown that accurate control of the moisture content of the cooked seed, in conjunction with pressure cooking at temperatures considerably higher than those met in usual practice, is capable of increasing the oil production by as much as ten pounds per ton of seed. Both the oil and cake produced are of greater uniformity and of as good or better quality than that produced by earlier processes.

The cooker's design and operation are fully described.

J. W. H.

Acrylic resins find industrial applications. D. S. FREDERICK. *Chem. & Met. Eng.*, **44**, 468–71 (Sept., 1937).—Polymerization products of acrylic acid and its derivatives are known as acrylic resins. Many derivatives of this acid such as salts, amides, nitrites, esters, and acid chlorides yield solid polymerization products. The esters are at present the most important commercially. They show colorless transparency, stability against aging, thermoplasticity, and chemical resistance to many reagents. They range from soft, sticky semiliquids to hard tough thermoplastic solids.

Light, heat, oxygen, and oxygen-yielding compounds are catalysts used in their manufacture.

They are used as an intermediate layer in laminated safety glass, for making cast or molded plastics, spectacle lenses, camera lenses, magnifying glasses, protective goggles, advertising displays, instrumental dials, inspection windows, boxes, buttons, handles, knobs, protective coatings, thermoplastic binders, and many novelty articles.

J. W. H.

The inert gases—their production and uses. H. S. COLTON. *Chem. & Met. Eng.*, **44**, 484–6 (Sept., 1937).—The average small house contains over two hundred cubic feet of argon which is worth almost that many dollars; while the neon contained in the same house is less than a quarter of a cubic foot, its market value is nearly $50.00 when pure. Argon now replaces nitrogen for filling incandescent lamps. Both xenon and krypton would

be even better for this, but their production is still too expensive. Neon is finding extensive use in signs and helium as a lifting medium for dirigibles and balloons. Helium is also used to dilute oxygen for breathing purposes where men must work under pressure.

In producing these gases they are first obtained as a concentrated crude gas which is later refined. The crude helium is obtained from some unusual wells in the southwestern states, and the crude concentrates of argon, neon, krypton, and xenon are obtained from liquid air columns. To get argon the oxygen is removed by burning out with hydrogen. It is then run over hot copper and copper oxide, dried, compressed and put up in cylinders. The product is eighty-six per cent. argon and fourteen per cent. nitrogen. The nitrogen can be removed by calcium and magnesium. The other inert gases are purified by similar methods. J. W. H.

A dusty discourse. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **128,** 3 (Sept., 1937).—A dusty discourse is an announcement concerning the silicosis problem that tiny traces of aluminum dust added to the silica-filled air may eventually stay the ravages of silicosis. The presence of aluminum seems to prevent the degeneration of the lung cells and the production of fibrous cells by inhibiting the rapid solution and concentration of the silicious material. Other research workers intimate that dusts like powdered coal, iron oxide, and alkaline earth carbonates also have a protective action. At a recent Department of Labor conference on silicosis, it was agreed that there should be coverage for silicosis in the compensation acts of all the states and research projects for the study of silicosis in relation to other diseases, especially tuberculosis. G. O.

Almost elemental. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **128,** 4 (Sept., 1937).—This is the story of super-purity in metals produced by almost unconventional methods of metal purification, producing super-pure metals used mainly on a microbasis as sources of arc or spark line spectra in the spectrographic study of metals and metallic compounds. G. O.

Fog as a cause of the deterioration of buildings and rocks and its influence upon agriculture. E. SCHNELLER. *Chem.-Ztg.*, **61,** 454–5 (June 2, 1937).—The acid gases, carbon dioxide, sulfur dioxide, sulfur trioxide, N oxides, etc., which are present in the atmosphere of large cities are dissolved in the moisture of the fog and then exert their destructive acid action upon buildings. In the country such fog causes the destruction of silicates and the solution of bicarbonates. L. S.

The construction of electrically heated laboratory ovens. M. MIELDS. *Chem.-Ztg.*, **61,** 516–7 (June 23, 1937).—Detailed directions are given for the construction of electrically heated laboratory ovens which will yield temperatures up to 1300°C. for any length of time and 1350°C. for shorter periods. Various stages in the construction of such ovens are shown by illustrations. L. S.

Reactions between potassium chlorate and ammonium salts. HANTKE. *Angew. Chem.*, **50,** 473–6 (June 26, 1937).—Mixtures of potassium chlorate and ammonium salts, or related compounds, react very rapidly and involve very complicated side and chain reactions. Typical equations follow: potassium chlorate and ammonium sulfate

$$20KClO_3 + 10(NH_4)_2SO_4 = 10K_2SO_4 + 20NH_4ClO_3$$
$$4NH_4ClO_3 = 4NH_3 + 4HCl + 6O_2$$
$$6KClO_3 + 4NH_3 = 4KNO_3 + 2KCl + 2Cl_2 + 6H_2O$$
$$8NH_4ClO_3 = 8HCl + 4N_2O_3 + 12H_2O$$
$$N_2O_3 + 2Cl_2 + 2H_2O = 4HCl + N_2O_5$$
$$N_2O_5 + H_2O = 2HNO_3$$
$$3N_2O_3\ 3H_2O = 6HNO_2$$
$$8NH_4ClO_3 = 12H_2O + 8HCl + 4N_2 + 6O_2$$
$$4KClO_3 = 4KCl + 6O_2$$

$$30KClO_3 + 10(NH_4)_2SO_4 = 10K_2SO_4 + 4KNO_3 + 6KCl + 24HCl + 18O_2 + 6HNO_2 + 2HNO_3 + 4N_2 + 24H_2O$$

Potassium chlorate and ammonium chloride

$$30KClO_3 + 20NH_4Cl = 20KCl + 4KNO_3 + 24HCl + 18O_2 + 6HNO_2 + 2HNO_3 + 4N_2 + 24H_2O$$

Potassium chlorate and other ammonium salts

$$30KClO_3 + 20NH_4X = 20KX + 4KNO_3 + 6KCl + 24HCl + 18O_2 + 6HNO_2 + 2HNO_3 + 4N_2 + 24H_2O$$

where X represents an acid radical. L. S.

Colorful pictures. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **128,** 1–2 (Sept., 1937).—To the camera "enthusiast" there is now available a "Wash-Off Relief Process" by which it is possible to produce photographic prints in natural color. The general fundamental principles of the process are old, but the process is new. It has no relation to the color camera which produces transparencies or films rather than photographic prints. The process is known as "imbibition printing." An ordinary camera with a reasonably fast lens makes three exposures of the subject with three filters designated as "Wratten" filters. The exposures are developed and fixed in the usual way producing three negatives known as color separation negatives. These negatives are used to print three positive images on a special emulsion on a very thin film base. The three positive exposures are then developed to completion in a regular Elon developer, but before fixing they are given a special chemical treatment in an acid bath of ammonium bichromate which dissolves out the silver and renders the exposed portion insoluble. The soluble gelatine composing the emulsion is washed off, thus producing a clear, colorless water-insoluble gelatine relief which can be fixed in a non-hardening bath, washed, and dried. If the process has been properly carried out, the films, now known as matrices, can be dyed in the appropriate dye solution. If transparency is desired, it may be obtained by the usual dyeing, registering them, and sandwiching them between pieces of clear glass. Each matrix properly handled will make about seventy-five transfers and is considerably cheaper than a printing plate. This imbibition printing offers possibilities for the reproduction of paintings, flowers, illustrated manuscripts, and the like in their true colors. G. O.

SCIENTIFIC REVIEWS AND BIBLIOGRAPHIES; TABULATIONS OF SCIENTIFIC DATA

The chemical industry of British India. F. WITTKA. *Chem.-Ztg.*, **61,** 290 (April 3, 1937).—An economic survey. L. S.

The quantitative emission spectrum analysis. K. CRUSE. *Angew. Chem.*, **50,** 397–400 (May 29, 1937).—General discussion of the quantitative spectrum analytical method; review of various errors and discussion of a generally applicable quantitative spectral analytical method. L. S.

Antioxidants and stabilizers for fats. F. WITTKA. *Chem.-Ztg.*, **61,** 386–9 (May 8, 1937).—Phenols like hydroquinone, pyrogallol, and quinone are the most efficient antioxidants for fats. Aromatic amines are less efficient. The efficiency of aliphatic acids and of carotines is still doubtful. The lecithines are good antioxidants, particularly in those cases where fats must be protected in the presence of traces of metals. The application of various antioxidants is covered by numerous patents. The patents taken out so far are listed under the following classes: inorganic ingredients, aliphatic acids, other aliphatic compounds, phenols, aromatic amines, amino-oxy compounds, condensation products, natural products, and stabilizers for soaps. L. S.

The inflammability of cork and wood dust. W. KÜHN. *Chem.-Ztg.*, **61,** 406–8 (May 15, 1937).—From the results of experiments it is concluded that cork dust has a more pronounced inflammability than wood dust. L. S.

The oxidation of organic compounds with atmospheric oxygen. A. RIECHE. *Angew. Chem.*, **50,** 520–4 (July 10, 1937).—A review covering the oxidation of aldehydes, ketones, olefines, saturated compounds, fatty acids, hydrocarbons, and ethers. L. S.

The chemical knowledge of the ancient Assyrians. R. WINDERLICH. *Chem.-Ztg.*, **61,** 428–9 (May 22, 1937).—A historical review. L. S.

Rhodium and its industrial uses. O. BRUNCK. *Chem.-Ztg.*, **61,** 433–5 (May 26, 1937).—A review dealing with the manufacture of rhodium, its properties and industrial uses. L. S.

The history of the Verein deutscher Chemiker. 1912–1937. P. DUDEN. *Angew. Chem.*, **50**, 501–4 (July 10, 1937).—A historical survey. L. S.

Carbon in the household of nature. W. NODDACK. *Angew. Chem.*, **50**, 505–10 (July 10, 1937).—A review. The carbon compounds, geochemistry of carbon, the carbon cycle, the carbon equilibrium in nature. L. S.

New problems of inorganic chemistry. W. KLEMM. *Angew. Chem.*, **50**, 524–35 (July 10, 1937).—A survey dealing with compounds between non-noble metals and non-metals, compounds between non-metals, intermetallic compounds, and transition elements. L. S.

Progress in the field of photography since 1930. W. MEIDINGER. *Angew. Chem.*, **50**, 553–60 (July 10, 1937).—A survey covering the methods of measuring photographic characteristics, ultra-red photography, color photography, direct positive films, and investigation of photographic processes. Thirty-seven references. L. S.

The removal of sulphur from mineral and tar oils. F. MUHLERT. *Chem.-Ztg.*, **61**, 425–8 (May 22, 1937).—A discussion of the nature of sulfur compounds occurring in technical hydrocarbon oils and a review of various industrial processes of removal of sulfur as refining with sulfuric acid, catalytic reduction with hydrogen, etc. Thirty-two references. L. S.

HISTORICAL AND BIOGRAPHICAL

International meeting of scientists at the Palais de la Découverte. M. POLANYI, J. G. CROWTHER, E. F. HARTREE, AND J. N. *Nature*, **140**, 710–4 (Oct. 23, 1937).—An international congress of chemists, physicists, and biologists was held in Paris at the Palais de la Découverte, "which represents a great effort of popularization on the part of French science, and is an attempt, and a very successful attempt, to parallel the South Kensington Science Museum and the Deutsches Museum." Delegates were present from England, the United States, Germany, Italy, Spain, Portugal, and Jerusalem. Japan and the U. S. S. R. were not represented. The opening speeches emphasized that "the link between science and liberty is completely reciprocal." Jean Perrin, president of the congress, asserted that the independent search for truth embodied in science is the best safeguard of civilization against threatening destruction. The speakers at the scientific meetings included, among others, P. Scherrer, J. D. Cockcroft, Niels Bohr, P. M. S. Blackett, P. Debye, Sir C. V. Raman, W. L. Bragg, L. Ruzicka, and E. K. Rideal. M. E. W.

The Right Hon. Lord Rutherford, 1871–1937. A. S. EVE, J. CHADWICK, J. J. THOMSON, W. H. BRAGG, N. BOHR, F. SODDY, E. N. DA C. ANDRADE, AND F. E. SMITH. *Nature*, **140**, 746–54 (Oct. 30, 1937).—Ernest Rutherford was born in New Zealand on August 30, 1871. With C. T. R. Wilson, Townsend, and H. A. Wilson, he studied at Cavendish Laboratory, Cambridge, under Sir J. J. Thomson. In 1898 he became research professor of physics at McGill University, Montreal, where he was joined by Frederick Soddy. Together they studied the relation between Thorium and Thorium X and put forth the bold theory of the spontaneous disintegration of radioactive elements. Rutherford's first book "Radioactivity" was written with "a breathless enthusiasm."

A great part of his life was spent in investigating the properties of alpha particles. "In 1904 Ramsay and Soddy definitely obtained the helium spectrum from aged radon, and five years later Rutherford and Royds collected the alpha particles, ejected from radon, after their passage through the exceedingly thin walls of a glass container. . .," and proved spectroscopically that they were helium atoms. Otto Hahn worked with Rutherford for a time at McGill and discovered radioactinium. Rutherford's "conception of the atom as a heavy, positively charged nucleus surrounded by a cloud of electrons in appropriate number" was first put forward at a meeting of the Manchester Literary and Philosophical Society. "The nuclear theory was the culmination of Rutherford's work on the alpha rays and the finest of all his great contributions to physics." In 1919 Rutherford left Manchester and succeeded J. J. Thomson as Cavendish Professor of Experimental Physics in Cambridge.

According to J. J. Thomson, Lord Rutherford's death on October 19, 1937, "just on the eve of his having in the High-Tension Laboratory means of research far more powerful than those with which he had already obtained results of profound importance, is, I think, one of the greatest tragedies in the history of science." M. E. W.

Lomonosov and early science in Russia. S. S. IVANOFF. *Nature*, **140**, 784–5 (Nov. 6, 1937).—B. N. Menschutkin has recently published a biography of M. V. Lomonosov (1711–65), who laid the foundation of Russian experimental science. For about thirty years Professor Menschutkin has been studying the Lomonosov manuscripts in the Academy of Sciences of the U. S. S. R. and has translated many of them from Latin into Russian. He has enriched the biography with many notes about Lomonosov's contemporaries. Lomonosov studied under Professor Chr. Wolfe at Marburg and translated Wolfe's experimental physics into Russian. Since the Russian language at that time had no scientific vocabulary, he created new words and expressions. In 1744 he published an elaborate dissertation on the corpuscular theory of matter. Professor Menschutkin compares Lomonosov with Mendeléeff. "They both show a remarkable similarity of their genius. Both were physical chemists, whose interest centered chiefly in a particular class of research —that of solvents. Both adopted a serene philosophical attitude in their teaching, and yet both remained practical workers; throughout their lives Lomonosov and Mendeléeff remained great Russian patriots endeavouring to bring scientific conquests within the reach of their Fatherland." M. E. W.

GENERAL

Following Paracelsus. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **129**, 1–2 (Oct., 1937).—A great concerted drive is being made against cancer with chemists, physicists, and biologists all working in coöperation with medical men. Cancer is of importance to industry, not alone in its direct effect on the personnel of the companies concerned, but by the reaction of the public to the insinuations that a particular product may cause cancer. Ultimately, convincing answers must be found for all unjustified claims that a certain oil or whatnot is cancer-inducing. Some industrial concerns have been farsighted enough to start long-time investigations of their own, the du Pont Company, for example, investigating the chemicals associated with dye manufacture, for cancer is said to be more frequent than usual among dye workers. In England a fund has been established to investigate spindle oils used in textile mills as well as lubricating oils. It is known that some crude shale oils cause cancer, although the refined oils apparently do not. Several of the research groups are synthesizing previously unknown derivatives of phenanthrene, anthracene, and other hydrocarbons that go with carcinogenic properties. Up to the present time, the most active chemical compounds found have been hydrocarbons. The testing is done on mice, for mice have cancers of the same general types that affect human beings. Human cancers may be caused by specific chemical irritants, but the majority of cases are probably not so initiated. It is possible that hormones are involved in many cases, in a chemical way. Some very fundamental cell physiology and chemistry are being studied to find out why certain body cells retrogress toward a degenerate state while often retaining functional activity. All this research work looks to the future, and it is to be hoped that useful findings will result in preventive measures being taken. G. O.

Why chemists get fired. *Chem. Industries*, **41**, 237–40 (Sept., 1937) **41**, 351–2 (Oct., 1937).—"So frequently do we hear adverse criticisms of the qualifications of the younger technical men employed in industry that with the purpose of determining whether this was primarily a problem of personality or of education, or of both, we have collected from representative operating and research executives in scattered fields their answers to the question 'Wherein do you find these men lacking for your work?' The answers published in *Chemical Industries* are extremely significant contributions to this fundamental problem." A. T. B.

RECENT BOOKS

GENERAL CHEMISTRY. *H. I. Schlesinger*, University of Chicago. Third edition. Longmans, Green and Co., New York City, 1937. ix + 857 pp. 86 figs. 14 × 21 cm. $3.50.

The third edition of this excellent text is more than ever committed to its original principle: "...that college chemistry, to be stimulating and of greatest value to the student, should, in contrast to high-school chemistry, be analytical rather than descriptive, and should be an intellectual exercise rather than a feat of memory."

It is still one of the very few college textbooks specifically designed for students with high-school preparation in the subject. Although descriptive matter is not entirely omitted, as from some other recent texts, it is not dressed up for public show. Readers are assumed to be already sufficiently impressed by the "marvels of modern chemistry."

The author prefaces the book with the suggestion that "the rapid development of important fundamental ideas of chemistry during the past few years makes necessary the inclusion of new concepts and principles even in elementary presentations of the subject." The book is particularly distinguished by its efforts to follow this policy.

The chapter on atomic structure has been completely rewritten and brought thoroughly up to date. Much more attention has been given to the bearing of this topic on valence, types of chemical union, and the comparative properties of the elements and their compounds. It contains an unusually clear and satisfactory treatment of electron arrangements within atoms and their significance. In only one instance does the author fail in his objective, and this is in the effort to picture the behavior of the electron in modern terms of probability. But when it is realized that this has seldom, if ever, been seriously attempted in an elementary textbook, the effort itself is commendable.

The groundwork for later study of thermodynamics is laid by a good treatment of heats of reaction and their significance. A good description is to be found of the various factors concerned in reaction velocity, including the activation of molecules, as well as an excellent discussion of catalysis. All of this, along with a brief introduction to chain reactions, the function of inhibitors and a little photochemistry, will lead the inquiring student into a deeper study of reaction mechanisms.

Abundant use is made of illustrations from the kinetic theory, and the properties of gases, liquids, solids, and solutions are unusually well treated from this standpoint.

It is inevitable that an author who is trying to develop new avenues of approach to his subject will be criticised for being too radical in some respects and too conventional in others. Some readers will be disappointed in not finding this book committed to the view which defines acids and bases in terms of simple proton exchange. Nevertheless, such a view is not incompatible with the rest of the book. Hydration of ions is by no means overlooked, but, although the reader is cautioned to remember that the proton is hydrated when it becomes a hydrogen ion, he is allowed to forget it by insufficient emphasis.

The positive-ray method of determining atomic weights deserves more attention than the brief mention under the heading of isotopes. The technic of X-ray analysis of crystals might well have a prominent place in the study of solids, rather than a minor one in connection with radioactivity.

The treatment of the important topic of ionization is neither radical nor altogether conventional. Eventually the student is brought to the generally accepted modern view of "degrees of ionization," although perhaps with more than the necessary time and struggle. It would no longer seem profitable to put much emphasis upon the data from freezing and boiling points, or even from conductivities, when the numerical results turn out to be fictitious in the great majority of cases. However, ample groundwork is laid in these chapters for the ambitious teacher to follow any advanced side-line he may desire.

In revising the book for this edition some fundamental changes have been made in the order of topics. The chapter on solutions has been moved up and included in the early discussion of the general kinetic theory, following the properties of gases, liquids, and solids. Metallurgy and the extraction of metals from their ores is dealt with immediately after the discussion of combustion and the energy changes in chemical reactions. The chapters on radioactivity and atomic structure are also moved forward, so as to make them more useful, without, however, allowing them to precede the necessary factual background. An entirely new chapter deals with reactions of oxidation and reduction.

The entire last half of the book has been changed only in so far as necessary to bring the descriptive material abreast of the latest advances.

NORRIS W. RAKESTRAW

BROWN UNIVERSITY
PROVIDENCE, RHODE ISLAND

LABORATORY MANUAL OF GENERAL CHEMISTRY. *H. I. Schlesinger* and *Adeline De Sale Link*, University of Chicago. Third edition. Longmans, Green and Co., New York City, 1937. vii + 96 pp. 8 figs. 13.5 × 21 cm. $1.50.

This manual is a companion to Schlesinger's GENERAL CHEMISTRY and is designed primarily for students with some previous experience with the subject. In it the authors "have considered training in scientific method, practice in coördinating information, and the development of a critical attitude toward experimental results, the main objectives."

With this preface, and in view of the sentiments often expressed by the senior author on the objectives of student laboratory work, one expects something more unusual than he finds. Thought-provoking questions are fairly numerous, and because of the amount of time presumably spent on these, the number of experiments has been advisedly kept small. Still, there is ample material for a course of average length, even though no work in qualitative analysis is included.

Alternate pages are blank, for the recording of notes. No set forms are provided for these—which will commend it to many teachers.

It is hard to avoid the feeling that the manual is not up to the high standard of the textbook.

NORRIS W. RAKESTRAW

BROWN UNIVERSITY
PROVIDENCE, RHODE ISLAND

ELASTICITY, PLASTICITY, AND STRUCTURE OF MATTER. *R. Houwink*, The University Press, Cambridge. The Macmillan Co., New York City, 1937. xviii + 376 pp. 214 figs. 13.5 × 21.5 cm. $6.00.

Other reviewers have already pointed out that this book begins with a non-mathematical statement of the elementary theory of rheology and that it then proceeds to give a more or less detailed statement of the rheological properties of a variety of industrial materials. These other reviewers have also listed the few errors which they have discovered. It is the purpose of the present reviewer to deal with an entirely different side of this book.

For over two years it has fallen to the lot of this reviewer to teach an elementary two-semester course in colloids. Anyone who has ever tried it will realize how difficult it is to find a suitable textbook. Almost all authors of books on colloids seem to feel that they must give a tiresome and impartial résumé of all the conflicting articles in colloid literature, so that their books

read like the writings "of the scribes and Pharisees" and not as "of one speaking with authority." None of the authors seem to have tried to assay the literature from the simultaneous viewpoints of both physics and chemistry. Practically all of them seem to live in mortal terror of leaving out of the body of their text the name of even a two by twice investigator. The result is that by the time the class has finished its first text on colloid "theory" at the end of the first semester, it has the jitters from an overdose of "A says 'tis, but B says 'taint."

All this makes the choice of a textbook for the second semester a delicate task. Since colloid theory, such as it is, has unavoidably been taken up during the first semester, it is reasonable to look for a book on the physical properties of colloid materials for the second semester. Books of this sort, suitable for college textbooks, are scarce, however.

With this problem on his mind, your reviewer started to read Houwink. He had not gone far before he had discovered that by omitting Chapter V (an admirable chapter of fifty-five pages by Dr. Burgers on the plasticity of crystals), he had almost exactly what he had been looking for. After forty-four pages of a review of elementary rheology, the author takes up the formation of "solid" matter from a fluid and its consequences with regard to viscosity, plasticity, and elasticity; the structure of heterogels; swelling; thixotropy; conditions for quasi-flow; conditions for rigidity. Then, starting with Chapter VI, he takes up the rheological properties of important colloids such as glass, resins, asphalts, rubber, cellulose compounds and related products, proteins, bread dough, paints, and clay. But these properties of thixotropy, plasticity, elasticity, and viscosity are the properties which give all these colloid materials their industrial value. Obviously, what the authors intended to be a book on applied rheology (and it is a good elementary treatise on rheology and its applications) comes very close to being a fine second-semester book on the industrial properties of colloids. At any rate, that is what your reviewer expects to use Houwink's book for next semester.

WHEELER P. DAVEY

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METHODS OF QUANTITATIVE CHEMICAL ANALYSIS. *M. G. Mellon*, Ph.D., Purdue University. The Macmillan Co., New York City, 1937. vii + 456 pp. 76 figs. 14 × 21 cm. $3.00.

Only a few years ago there was a decided dearth of good textbooks for the presentation of theory and experiment in quantitative analysis. Within a very short period of time, however, several new and noteworthy contributions to this field have appeared. It is evident that almost every author on the subject of quantitative analysis has taken it upon himself to write a book which meets the particular needs of his own teaching and which is based upon his own experience. The latest of this series of texts comes from the pen of a man who has established a very enviable reputation as an analytical teacher and investigator.

Modern texts in quantitative analysis must differ necessarily not so much in subject matter as in the classification of methods, the order of experimentation, the coördination of theory with practice, and the inclusion or exclusion of a larger variety of methods, largely instrumental, than elementary texts usually include. So the present book presents certain unique features not to be found in other competitors.

The first three chapters deal with a general introduction, the recording, evaluation, and use of experimental data and managing of quantitative work. Part I deals with the sample, its selection and preparation, the measurement by mass and by volume, and the preliminary treatment of the sample. Part II has the title "The Desired Constituent" with, first, the methods of separation including volatilization, precipitation, electrochemical, and extraction methods; then follow the methods of measurement. These are classified under specific property methods and systemic property methods. Under the first are included mass indirectly, titrimetric methods involving neutralization, oxidation-reduction and precipitation; and next, mass directly or gravimetric methods, volume and volumetric methods, pressure and manometric methods, temperature and thermometric methods.

Thus Professor Mellon, in agreement with other authors, prefers to present the volumetric procedure first. Under systemic property methods appear density and specific gravity, opticochemical methods, electrometric methods, and other methods. An appendix includes references, additional applications, an outline of work for two semesters, a list of analyzed samples, specific gravities, and a graphic logarithm table.

It is evident from the table of contents that no separate treatment is given to the theory upon which quantitative procedure is based. This theory appears to be incorporated directly with the treatment of the subject matter. One might even gain the impression that the theoretical aspects have been somewhat minimized and it is true that actually only a minimum of theoretical presentation appears although adequate for understanding by the average college sophomore. The entire procedure reflects very careful thought and long experience, even though the experimental side is stressed far beyond any theoretical aspects.

Use is made to an unusual degree of what may be termed "word coinage." Such words as "permanganimetry," "reductimetry," "thiosulfatimetry," "ferrousimetry," "ferrocyanimetry," "opticometry," "roentgenometry," etc., convey the meaning, but it is to be questioned whether some of these very awkward words are not better replaced with the more familiar and usual combinations of words.

The lists of problems at the end of most of the chapters are limited but appear to be adequate for illustrating general principles. It is the expectation of the author that the instructor using the book will add exercises as may seem desirable.

While there can be wide differences of opinion as to the method of presentation, there is unquestionably a certain clear logic in the development, and the chosen experiments are certainly those that can be used in the average college laboratory for the development of technic and for illustration of principles. The mechanics of the book are excellent with the usual strong waterproof binding. The text seems to be free from error and, as stated before, reflects in every detail the painstaking and enthusiastic regard by the author for his chosen field of work. Especially for two-semester courses in quantitative analysis, this new text should have wide acceptance.

G. L. CLARK

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A COMMENTARY ON THE SCIENTIFIC WRITINGS OF J. WILLARD GIBBS, Volume I, Thermodynamics; Volume II, Theoretical Physics. Edited by *F. G. Donnan* and *Arthur Haas*. Yale University Press, New Haven, Connecticut, 1936. xx + 605 pp. 14.5 × 22.5 cm. $10.00.

In 1906, a few years after the death of Josiah Willard Gibbs, his scattered papers together with some previously unpublished writings were collected, grouped according to subject, and published as THE SCIENTIFIC PAPERS OF J. WILLARD GIBBS. It was not until 1928 that the first complete edition of Gibbs's published writings appeared in two volumes entitled, THE COLLECTED WORKS OF J. WILLARD GIBBS. The later compilation contained all of the material included in the first, and in addition, ELEMENTARY PRINCIPLES IN STATISTICAL MECHANICS, which had been published by Gibbs as a book. Though these editions of his papers have made Gibbs's writings conveniently accessible, many readers have found that "the generality and abstract nature of the reasoning" made his methods difficult. To facilitate and supplement the study of his writings is one of the two purposes of the beautiful new volumes which bear the title, COMMENTARY ON THE SCIENTIFIC WRITINGS OF J. WILLARD GIBBS. The other and

primary objective of the COMMENTARY is to honor the memory of Professor J. Willard Gibbs, himself.

The writing and printing were done under the auspices of Yale University and were financed partly by the University and partly by Professor Irving Fisher who has been a major force behind the whole memorial project. Actual work on the COMMENTARY began in 1929 and was brought to completion about four years later.

Volume I deals with Gibbs's thermodynamical writings included in the first volume of each of the two editions of his papers. It was edited by F. G. Donnan and Arthur Haas. The contributing authors include Donald H. Andrews, J. A. V. Butler, E. A. Guggenheim, H. S. Harned, F. G. Keyes, E. A. Milne, George W. Morey, James Rice, F. A. H. Schreinemakers, and Edwin B. Wilson. Most of the articles are discussions of certain designated parts of Gibbs's papers, and were written to aid the readers of those papers. They also include discussions of some modern developments. Professor Wilson's article is an outline of a series of lectures on thermodynamics given by Gibbs in the year 1899–1900.

Volume II, edited by Arthur Haas, contains articles contributed by Paul S. Epstein, Arthur Haas, Leigh Page, and Edwin B. Wilson. It deals chiefly with the statistical methods of Gibbs, but includes also two thermodynamical articles, one on the "Theory of Light" and an article on "Vector Analysis and Multiple Algebra."

The volumes are beautifully printed and bound in a style matching the binding of THE COLLECTED WORKS OF J. WILLARD GIBBS. It seems likely that every serious student of thermodynamics or of statistical mechanics will want to consult this scholarly and interesting COMMENTARY.

T. F. YOUNG

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AN INTRODUCTION TO PHYSICAL CHEMISTRY. *F. A. Philbrick*, M.A. (Oxon.), Late Scholar of Balliol College, Assistant Master at Rugby School. J. M. Dent and Sons Ltd., Bedford St., London, W. C. 2, 1937. ix + 368 pp. 118 figs. $1.25.

This book is written for English students who have had the background of a School Certificate and are working for the examinations for the Higher Certificate. The material is largely descriptive, and calculus is used only in the discussion of reaction rates. The subjects covered are atoms and molecules, solutions, homogeneous equilibrium and reaction rate, ionic reactions and properties of electrolytes, heterogeneous equilibrium, crystal structure, colloids, and a short discussion of qualitative and quantitative analysis. This indicates that the book should be classified for use in this country as a second-year college text and not for a junior or senior course in physical chemistry. To one who wishes to obtain further information with a general chemistry background, but does not intend to pursue the details of physical chemistry, the book can be recommended as of value.

ARTHUR A. VERNON

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SMITH'S INORGANIC CHEMISTRY. *James Kendall*, F.R.S., Professor of Chemistry in the University of Edinburgh; formerly Professor of Chemistry at Columbia University and at New York University. Second revised edition. D. Appleton-Century Company, Inc., New York, 1937. xxiv + 954 pp. 222 figs. + 19 full-page illustrations. 15 × 21 cm. $4.00.

Although the author gracefully bows to Alexander Smith it is obvious that, in keeping abreast of developments through several revisions, Professor James Kendall has produced a text which is essentially his own.

Those familiar with the older editions will be pleased with the sustained and lively interest in the history of chemistry and the sympathy with both student and teacher which have characterized every Smith text. In developing the newer knowledge of structure, valence, oxidation and reduction, transmutation, polar and non-polar compounds, equilibrium, and solutions, the author has been consistently careful to present the experimental evidence and to outline in simple terms the essential differences between the new and the old theories, for which older teachers will be profoundly grateful.

The author frequently intersperses paragraphs of warning against popular misconceptions and periodically pauses to consolidate progress on various fronts. Noteworthy are the paragraphs devoted to the evolution of our interpretation of the term element, the chapters reviewing the metallic and the non-metallic elements, and a unique compilation of principles (pp. 287–289). The several chapters dedicated to plant life, plant growth, and plant products should be read by every student of physics, biology, and chemistry.

Throughout is the typical Kendall touch—a combination of colorful expression and of subtle, whimsical humor. If, for no other reason, the reader would be kept at a high level of interest by the prospect of discovering some hidden barb intended for the teacher, student, investigator, or even the author. For example, "If this tremendously exothermic reaction (mass→energy), once started, were to get out of control and proceed explosively, all of the hydrogen on the earth might be transformed at once and the success of the experiment signalled to the rest of the universe by the appearance of a new and exceedingly bright star." "Diving deep down into the waves with all the latest mathematical equipment, Schrödinger finally emerged with some involved equations in his grasp. . ." "Hypotheses are. . .scaffolding temporarily employed to facilitate the erection of the structure of the science." "The Bishop of Würzburg used to maintain a special gallows in his diocese upon which to hang chemists. Many college students would no doubt be glad to see this pleasant custom revived."

If one were to create the term "factual vapor tension" it could well be applied to the exercises at the end of each chapter. These searching review questions, based upon the text and refined by the compiler's long and successful teaching experience, constitute one of the most valuable features of the text.

There is a satisfactory balance between descriptive chemistry and principles, and the two are happily interwoven. But, in comparison with the principles of chemistry and with the nonmetallic elements, some of the metals suffer from textual atrophy. Here, the emphasis often reflects commercial uses and importance rather than the specific properties of the elements themselves. Charts showing family relationships and variations among the metals begin and end with the first group.

Very few inaccuracies came to the attention of the reviewer—among them the commercial production of barium by the electrolysis of the fused chloride, the continued operation at Notodden of the Birkeland-Eyde process, and the description of thermit as a mixture of "aluminium powder and ferric oxide," rather than of granular aluminum and ferrosoferric oxide. Typographical errors are almost nil. There are several minor inconsistencies. Three successive paragraphs devoted to the preparation of hydrogen are entitled, respectively ". . .by the Action of Metals on Cold Water," ". . .from Metals and Water at a High Temperature," and ". . .by Displacement from Dilute Acids." In writing thermochemical equations (of which there are still too few!), the author represents endothermic changes sometimes by a plus sign on the left-hand side and sometimes by a minus on the right. The lucid paragraphs devoted to atomic hydrogen on pages 510 and 534 under the general subject of nitrogen could profitably have appeared in part under the chemical properties of hydrogen on page 140. On page 725 appears this statement, "A saturated solution is a system with three phases," although it is obvious from the context that the presence of undissolved solute is assumed.

The text is equipped with an excellent index which increases its value as a reference. The type is easy, and, with the exception of Figure 185, the illustrations, tables, and diagrams are clear. The following supplementary material is contained on the inside covers and in the appendix: solubility of one hundred forty-three bases and salts in water at 18°C.; international atomic weights, 1936; customary metric units of length, volume, and weight; hardness scale; Fahrenheit-Centigrade conversion scale (40–100°C.); vapor pressures of water (0–100°C.); list of most common valences

and charges; prices of important chemicals as of February, 1937; list of Nobel Prize winners in chemistry; four-place logarithms. The book references were enlarged to include some of the excellent monographs which have appeared in recent years.

The whole text is so dynamic, the explanations so transparent, and the illustrations so alluring that the young teacher may find it difficult to inject his own personality into his teaching while using it as a text. For example, he must join Kendall wholeheartedly in scrapping the term nascent and in other pleasant adventures. As a teacher's companion, however, the book is priceless. The casual reader must be cautioned against lifting definitions out of their context in the early pages, for the author has chosen to allow certain ideas to evolve slowly, with the result that a complete picture may be had only in perspective after the text has been completed.

All in all, in this most recent edition of an already famous book, the author has again succeeded in setting a goal for other writers.

Ross A. Baker

The College of the City of New York
New York City

American Red Cross First Aid Textbook (Revised Edition). P. Blakiston's Son & Co., Inc., Philadelphia, Pa., 1937. vi + 256 pp. 144 illustrations. 20 × 30 cm. $0.60.

This is a very complete handbook of first-aid practice and is a handy adjunct for any chemical laboratory. The instructions for all kinds of treatment are concise and yet thorough. Among the chapter headings are Anatomy, Dressings and Bandages, Wounds, Shock, Poisons, Unconsciousness, Transportation and First-Aid Kits. Not only are the directions complete for each procedure, but the illustrations are so planned that every step is well illustrated. The chapter on injuries due to heat and cold is of especial interest to those engaged in any kind of laboratory work. The chapter on poisons is of interest, but does not contribute much of new interest. It is not, of course, concerned with industrial poisoning which is another subject. Primarily the book deals with emergencies, as would be expected. The revisions have been mainly concerned with new technic in the case of fractures.

Because of its completeness and authoritativeness, it can be highly recommended as a valuable adjunct to anyone who has anything to do with laboratories, or, for that matter, to anyone who may be in the position to render first aid, which includes almost all of us these days.

Edwin C. Buxbaum

4455 N. Maryland Ave.
Milwaukee, Wisconsin

Thorpe's Dictionary of Applied Chemistry, Volume I. *J. F. Thorpe*, C.B.E., D.Sc., F.R.S., F.I.C., Professor of Organic Chemistry and Director of Organic Laboratories, Imperial College of Science and Technology, and *M. A. Whiteley*, O.B.E., D.Sc., F.I.C., lately Assistant Professor of Organic Chemistry, Imperial College of Science and Technology. Fourth edition. Longmans, Green and Company, New York City. xxvii + 703 pp. 14.9 × 22.6 cm. $25.00.

"The great changes which have occurred since the publication of the original edition of the Dictionary have rendered it necessary to commence a new edition, of which this is Volume I. In the future it is proposed to issue one volume a year, and it is hoped that the work will be completed in nine volumes. The supplementary volumes to the existing edition which appeared in 1934 and 1935 were not, strictly speaking, true supplements, but rather a collection of monographs on special subjects concerning which the most striking advances had been made. They were, in a sense, self-contained, although dependent on the existing edition for continuity.

"In the forthcoming edition the Dictionary style will be readopted but, as described in the Foreword, the plan has been introduced of making each volume a means of bringing the contents of an earlier or later volumes up to date."

Educational, Psychological and Personality Tests of 1936. *Oscar K. Buros*, Rutgers University. Published by the School of Education, Rutgers University, 1937. 141 pp. 15 × 23 cm. Paper-bound, $0.75.

"Practically all 1936 pencil-and-paper tests published as separates in the United States and the British Empire are included in this volume. Tests published for use in state-wide testing programs are included whenever such tests are commercially available in other states. In addition to the classes of tests listed in the 1933–35 bibliography, the present issue includes numerous tests constructed for use with specific textbooks and for practice purposes."

A Hundred Years of Chemistry. *Alexander Findlay*, Professor of Chemistry in the University of Aberdeen. The Macmillan Co., New York City, 1937. 352 pp. 13.7 × 21.5 cm. $4.25.

This is a meaty history of modern chemistry, a chemist's history of the development of his science, not a popular book. It would be an extremely well-informed chemist who could read this book and fail to find in it new information on subjects closely related to his own. Many subjects he will find here treated better, more clearly, more fully, than in the textbooks which are under his hand, the reason being that the textbooks set down more or less dogmatically what the ideas are, while this book tells how the ideas grew and became what they are—and supplies an exposition which promotes understanding. The book will be of great value to teachers who are planning new courses, or revising old ones, in any of the branches of chemistry. It will be invaluable to students preparing for doctor's examinations, or to others who wish for a broad view of the whole subject.

Professor Findlay has done a thorough and scholarly job. The discussion throughout is supported by references to the original literature. The years of birth and death are generally given for chemists who are not now living. Numerous men and events are mentioned which have escaped the notice of some of the writers on the history of chemistry, for example, Thomas Sterry Hunt in connection with Gerhardt and the theory of types, Josiah P. Cooke in connection with the development of the periodic table, and Krönig and Waterson in connection with the kinetic theory of gases.

The first chapter discusses "The Historical Background" up to the time of Liebig and Wöhler and Berzelius, and the early studies on the benzoyl radical and on isomerism. The other chapter headings are as follows: II. The Development of Organic Chemistry, 1835–1865; III. The Determination of Atomic Weights and the Classification of the Elements; IV. Stereochemistry; V and VI. The Rise and Development of Physical Chemistry in the Nineteenth Century, I and II; VII. Organic Chemistry in the Second Half of the Nineteenth Century. The Synthesis of Organic Compounds, and the Theories of Chemical Structure; VIII. The Rise and Development of Chemical Industry Based on Coal Tar; IX. The Constitution and Synthesis of Naturally Occurring Compounds; X. The Discovery of New Elements. The Rare Gases; XI. Radioactivity and Atomic Constitution; XII. Physical Chemistry and Chemical Theory in the Twentieth Century; and XIII. The Development of Industrial Chemistry. Each chapter is an excellent treatment of its subject. The volume concludes with an appendix which contains short biographical sketches of sixty chemists, among whom the English-born John William Draper, the first President of the American Chemical Society, is the only American. The list could be improved, but it has the merit of containing in certain cases information which is not readily accessible elsewhere. The book is equipped with an adequate and serviceable index.

Tenney L. Davis

Massachusetts Institute of Technology
Cambridge, Massachusetts

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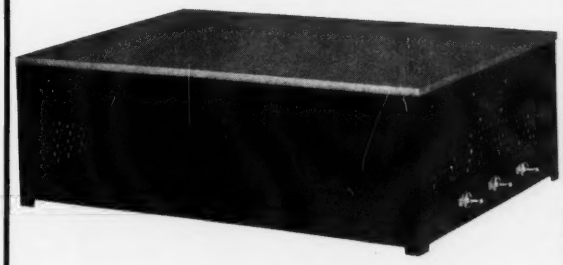

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TRADE ANNOUNCEMENTS

Apparatus Catalog for Hydrogen-Ion Concentration

A thirty-two-page catalog (EN-96) on apparatus for hydrogen-ion concentration (pH) measurements in laboratory and plant has just been issued by *Leeds & Northrup Company, 4934 Stenton Avenue, Philadelphia, Pennsylvania.*

The catalog describes and lists the latest forms of L&N electrodes, potentiometers, a potentiometer-electrometer, and galvanometers for determining the pH of aqueous solutions for research and analytical purposes in the laboratory and for process control in the plant. For the latter purpose, equipment is described for spot tests, and for continuous recorded measurement, which, in the case of certain specific processes, leads to continuous recorded measurement with automatic control.

Grasselli Publications

Among several new and revised pamphlets and folders which the *Grasselli Chemicals Department, E. I. du Pont de Nemours & Company,* has just prepared is a chemical catalog listing all of the products of that department in alphabetical order. The pamphlet, pocket size, contains a list of approximately three hundred thirty products with brief explanations, in some instances, of the use of these products. An illustrated folder on C.P. Reagents, carrying the analyses on the labels of those pictured, describes the manner in which these products are shipped.

A new pamphlet on Nogas, called an aid to pickling iron and steel, and a revised booklet on inhibitors, are two others just prepared. An explanation that Nogas is a powdered compound, its methods of application and its functions are given. It also carries a list of chemicals for the iron and steel industry. The pamphlet on inhibitors refers to the functions of an inhibitor and discusses briefly the powdered and liquid types.

The method of using electrolyte in batteries and the results to be expected are contained in a new pamphlet, which also carries a list of "safety hints" for those handling the acid while engaged in battery work.

A new pamphlet on tri-sodium phosphate explains that the product is a white crystallin chemical, is almost instantly soluble in water and that it makes hard water soft and contains no soap. A list of its uses is also given.

There are several new and revised pamphlets on the uses of insecticides and fungicides. These include new ones on the use of arsenate of lead, the combined spreader sticker, the control of corn earworm with Dutox, how and when to spray and dust fruit trees, vegetables, plants, and ornamentals, and on Sulforon, a fungicide.

The revised pamphlets, which describe the newer and what are considered the better methods of control, discuss the use of NuRexform Arsenate of Lead in pest control, the use of zinc sulfate to prevent pecan rosette, and the control of the peach borer. Each of these new and revised pamphlets goes into the various subjects in detail, discussing uses generally, including methods, quantities, and seasons when they should be applied.

Science Abstracts

Science Abstracts, issued monthly by the Institution of Electrical Engineers, London, is now available through the *Chemical Publishing Company of New York, Inc.*, its American agents.

Science Abstracts consists of two sections giving abstracts of technical journals throughout the world. Section A covers Physics and Section B, Electrical Engineering. *Science Abstracts* is a necessity in all research laboratories and libraries. Sample pages are available to all those interested.

Laucks Notebook

The staff of *Laucks Laboratories, Inc.*, and *Laucks Laboratories, Ltd.*, have, after much discussion, come to the conclusion that information and data accumulated by them during their many years of operation might prove of interest to clients and to friends.

Therefore, after a lapse of some years, "Laucks Notebook" returns, to abstract these notes.

It will be issued on a bi-monthly basis. If there are special subjects you or your friends would like covered herein, the company will be glad to furnish the notes they may have. Likewise, suggestions for improvement of the "Notebook" will always be welcome.

A New Ceramic Material for Laboratory Table Tops

Stuart M. Phelps and Edward E. Marbaker of *Mellon Institute* have described the development of a new laboratory table-top material called "Kemite." Its properties are such that it fulfils the exacting requirements of scientific laboratory service and does not have any of the disadvantages of the materials commonly used for this purpose.

Kemite consists essentially of an easily moldable ceramic body into which has been incorporated carbonaceous substances to increase the porosity after firing. It also contains artificially prepared cordierite, a mineral having an exceptionally low thermal expansion. This body, after molding, drying, and firing, is completely impregnated under pressure with liquid bitumens, and then subjected to a heat treatment during which the volatile matter is expelled. A residue of carbon in the form of coke fills the pores, rendering the body dense and imparting to it an attractive, black color. Kemite is smooth, hard, strong, practically impervious to liquids, and very resistant to the action of acids and alkalies. Because of its low thermal expansion, when locally heated and cooled rapidly, it does not crack or spoil. It retains its pleasing appearance under severe laboratory conditions.

While developed primarily as a table-top material, the characteristics of Kemite suggest its use in other kinds of laboratory and chemical plant equipment. In another form called "Karcite," in which cordierite is not present, it is being used for sinks, tanks, drain pipe, pipe fittings, and window sills. In building construction, it can be employed in such forms as sanitary ware, partitions, roofing, flooring, wainscoting, stair treads, and shelves.

Other information about Kemite and Karcite may be obtained from *Mellon Institute, Pittsburgh, Pa.*

Laboratory Thermometer and Hydrometer Catalog

The C. J. Tagliabue Manufacturing Company of Brooklyn, New York, announce the publication of a new TAG Laboratory Thermometer and Hydrometer catalog, No. 1100A.

In addition to the regular line of extreme precision and standard grade TAG thermometers and hydrometers, this valuable, new catalog now includes complete listings of the widely used A.S.T.M. thermometers with illustrations, also the well-known TAG-A.S.T.M. thermometers with illustrations, and the well-known TAG-A.P.I. and TAG certified hydrometers.

Useful data including comparison scale graduations, corrections for emergent stems, instructions for using hydrometers and fahrenheit and centigrade conversion tables are retained and amplified.

A catalog will be sent free by the manufacturer on request.